Erie-Niagara Basin

Ground-Water Resources

ERIE-NIAGARA BASIN REGIONAL WATER RESOURCES PLANNING BOARD

THE NEW YORK STATE WATER RESOURCES COMMISSION

CONSERVATION DEPARTMENT • DIVISION OF WATER RESOURCES

ENB-3

GROUND-WATER RESOURCES OF THE ERIE-NIAGARA BASIN, NEW YORK

EXCELSIOR

Prepared for the
Erie-Niagara Basin Regional Water Resources
Planning Board

by

A. M. La Sala, Jr.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
in cooperation with
THE NEW YORK STATE CONSERVATION DEPARTMENT
DIVISION OF WATER RESOURCES

STATE OF NEW YORK
CONSERVATION DEPARTMENT
WATER RESOURCES COMMISSION

Basin Planning Report ENB-3
1968

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ACKNOWLEDGMENTS

This report has been prepared for the Erie-Niagara Basin Regional Water Resources Planning Board under the general guidance of Mr. R. C. Heath, former District Chief and his successor Mr. G. G. Parker both of the United States Geological Survey's Albany, New York District Office.

The cooperation of the many local, State and Federal agencies who have provided valuable data and assistance is greatfully acknowledged.

GROUND-WATER RESOURCES OF THE ERIE-NIAGARA BASIN, NEW YORK

By
A. M. La Sala, Jr.

ABSTRACT

The Erie-Niagara basin, New York, borders Lake Erie and the Niagara River and includes the principal part of their drainage basin in New York. The area extends from the Cattaraugus Creek basin on the south to the Tonawanda Creek basin on the north. The northern part of the area and a narrow belt along Lake Erie are in the Erie-Ontario Lowlands, a region of low relief. The remainder of the area lies in the Appalachian Uplands, an area of considerable relief.

The principal water-bearing formations in the area are glacial sand and gravel deposits; the Camillus Shale, which contains interbedded gypsum; a limestone aquifer unit consisting of the Onondaga Limestone, Akron Dolomite, and Bertie Limestone; and the Lockport Dolomite. A number of thick and permeable sand and gravel deposits lie in valleys of the upland region and will yield supplies of 500 to 1,400 gpm (gallons per minute) to individual wells that are properly constructed. Several communities now obtain public water supplies from such deposits. The Camillus Shale, limestone unit, and Lockport Dolomite vary widely in water-bearing characteristics. Generally, only small to moderate supplies (less than 50 gpm) are available from these formations. However, where the water-bearing openings have been widened by solution of gypsum and carbonate minerals, the rocks provided large supplies. In and near Buffalo and Tonawanda, the Camillus Shale yields 400 to 1,200 gpm to individual wells, and the limestone unit yields as much as 300 gpm but more usually 100 gpm. The Lockport Dolomite does not yield more than 90 gpm to individual wells in the area. Data from nearby areas indicate the Lockport only occasionally yields as much as 100 gpm. Only small yields from wells, about enough for individual domestic supplies, can be obtained from shale, lake deposits, and till.

Average annual recharge to the sand and gravel deposits in the upland region ranges from about half a million to 4 million gallons per day per square mile. As the larger deposits are each several square miles in extent, the potential for development is large. To this potential should be added infiltration from streams that could be induced by pumping large quantities of ground water.

The quality of ground water in the Appalachian Uplands is marked by a high hardness but generally not by other unfavorable characteristics. The ground water in the Erie-Ontario Lowland generally is harder and otherwise poorer in quality, being high in dissolved solids. The water in the Camillus Shale is objectionably high in sulfate and, in some areas, chloride. The chloride may be dissolved out of deeply buried salt beds by water circulating through a regional flow system from a recharge area in the Appalachian Uplands to a discharge area along Tonawanda Creek. Shallow ground water in carbonate rocks and sand and gravel deposits locally has been polluted by septic tank effluent.

INTRODUCTION

PURPOSE AND SCOPE

This report presents the results of an investigation by the U.S. Geological Survey conducted for the Erie-Niagara Basin Regional Water Resources Planning Board. The area of study, called "Erie-Niagara basin" in this report, extends from the Cattaraugus Creek basin on the south to the Tonawanda Creek basin on the north, and includes Grand Island as shown in figure 1.

Figure 1.--Location map of the Erie-Niagara basin.

The plan of study called for the Geological Survey to provide the Planning Board with an evaluation of the ground-water resources of the Erie-Niagara basin and a description of the geology to the extent required for broad planning of water-resources development. Evaluation of the ground-water resources included appraising the quantity and quality of water available for development, its areal distribution, and seasonal variations. Existing and potential pollution and their effect on the availability of ground water were also included in the work.

The Geological Survey's investigations followed several lines of attack, and the most important of these are described below.

A major endeavor was to define the areal extent, lithology, thickness, and water-bearing properties of the geologic units. The unconsolidated deposits were mapped during field-reconnaissance studies (pl. 3). A previously published map of unconsolidated deposits (Kindle and Taylor, 1913) was available for a northern segment of the area and this mapping was slightly revised for the present report. Geologic maps and descriptions of the bedrock units were previously published (Broughton and others, 1962) and further bedrock mapping was not required for this report. About 400 wells and several springs distributed through the various geologic units were inventoried in order to define the water-bearing properties of the units. The data for all wells and springs mentioned in this report or indicated on maps are given in tables 6 and 7, respectively. Data on wells collected during previous studies of the Buffalo area (Reck and Simmons, 1952) and of the Western New York Nuclear Service Center site at Ashford were also used. Hydraulic properties of the more productive water-bearing units were studied by means of specific-capacity and pumping-test data.

The quantity of ground water discharging to the streams was estimated from streamflow data and the fluctuations of ground-water levels. The quantity of ground water available for development in the principal unconsolidated aquifers was estimated from data on ground-water discharge, geology, and topography.

Data on the chemical quality of ground water were obtained by sampling wells and streams at base flow. The analytical results for about 270 samples from about 250 wells are given in this report in tables 8 and 9. Chemical analyses of streamflow are given by Archer and others (1968). The New York State Division of Water Resources facilitated the evaluation of ground-water pollution by providing data on sanitary analyses of samples from more than 700 wells that were made by the several County Health Departments of the area.

WELL-NUMBERING AND LOCATION SYSTEM

The wells, springs, and miscellaneous sites of geologic or hydrologic information described in this report are numbered according to a grid system based on latitude and longitude. The Erie-Niagara basin lies between latitude 42°16' and 43°11'N and between longitude 78°06' and 79°03'W. The grid is composed of quadrangles of 1 minute of latitude and

and longitude. Each well number consists of three parts: first, the digits of latitude, such as 231 for 42°31' (omitting the digit "4"); second, the digits of longitude, such as 842 for 78°42' (omitting the digit "7"); and, third, the number assigned to the well with the 1-minute quadrangle. The complete well number of the first well listed within the 1-minute quadrangle described above is 231-842-1, as illustrated in plate 1. The location of each well is indicated by a circle in the plate. Where two or more wells are close together, a single circle is used to mark their locations and the last digits of the well numbers, set off by commas, are given as illustrated in plate 1 for wells 230-840-1 and -2.

A spring is numbered by the same system used for wells, except that the letters Sp are added, such as with spring 229-842-1Sp (pl.1). A site at which only geologic or miscellaneous observations were made is identified by a letter following the grid numbers, such as 221-840-A. Springs and miscellaneous sites are also distinguished by different location symbols as shown in plate 1.

On the well-location map in this report (pl.1), the three-digit numbers of latitude and longitude designations are shown along the margin of the map, and only the number of the site within each 1-minute quadrangle is shown with the appropriate well, spring, or miscellaneous-site symbol.

GEOLOGY AND TOPOGRAPHY

The Erie-Niagara basin is underlain by layers of sedimentary bedrock which are largely covered with unconsolidated deposits. Descriptions of the various bedrock units are given in figure 2. The bedrock consists mainly of shale, limestone, and dolomite; the Camillus Shale contains a large amount of interbedded gypsum. All the bedrock units were built up by fine-grained sediments deposited in ancient seas during the Silurian and Devonian Periods and, therefore, are bedded or layered. The dip of the rocks (inclination of the bedding planes) is gently southward at from 20 to 60 feet per mile, but the average dip is between 30 and 40 feet per mile. The dip is so gentle that it is hardly perceptible in outcrops.

The unconsolidated deposits are mostly glacial deposits formed during Pleistocene time about 10,000-15,000 years ago when an ice sheet covered the area. The glacial deposits consist of: (1) till, which is a nonsorted mixture of clay, silt, sand, and stones deposited directly from the ice sheet; (2) lake deposits, which are bedded clay, silt, and sand that settled out in lakes fed by the melting ice; and (3) sand and gravel deposits, which were laid down in glacial streams. The glacial sand and gravel deposits are of both the ice-contact and outwash types, as will be explained later in the report. The glacial deposits generally are less than 50 feet thick in the northern part of the basin. They are considerably thicker in some valleys in the southern part and reach a maximum known thickness of 600 feet near Chaffee. Other unconsolidated deposits are alluvium formed by streams in Recent times and swamp deposits formed by accumulation of decayed plant matter in poorly drained areas.

Relief of the present land surface is due to preglacial erosion of the bedrock and subsequent topographic modification by glaciation. In contrast to the southward dip of the rocks, the land surface rises to the south largely because preglacial erosion was more vigorous in the northern part of the basin. The shale in the southern part of the basin is somewhat more resistant to erosion than the rocks in the northern part of the basin but not significantly so. Figure 3 shows the relationship of the topography and rock structure and delineates the two topographic provinces of the basin: the Erie-Ontario Lowlands and the Appalachian Uplands. The rocks crop out in belts which trend generally east-west. The bedrock geologic map, plate 2, shows that the outcrop belts bend around to the southwest near Lake Erie. They assume this direction mainly because relatively intense erosion in the Erie-Ontario Lowland near Lake Erie has exposed the rock at lower elevations than farther east. The Lockport Dolomite and the Onondaga Limestone, because they are relatively resistant to erosion, form low ridges in the northern part of the basin. Tonawanda, Murder, and Ellicott Creeks descend the escarpment of the Onondaga at falls and cataracts.

In the hilly southern half of the basin (the Appalachian Uplands), preglacial valleys, deepened by glacial erosion, are cut into the shale. The valleys are partly filled with glacial deposits so that some of the present streams flow 200 to 600 feet above the bedrock floors of the valleys as shown in figure 3.

System	Series	Group	Formation	Thickness in feet	Description
Devonian	Upper	Conneaut Group of Chadwick (1934)		500	Shale, siltstone, and fine-grained sandstone. Top is missing in area.
Devonian	Upper	Canadaway Group of Chadwick (1933)	Undivided	600	Gray shale and siltstone, interbedded. (section broken to save space)
Devonian	Upper	Canadaway Group of Chadwick (1933)	Perrysburg	400-450	Gray to black shale and gray siltstone containing many zones of calcareous concretions. Lower 100 feet of formation is olive-gray to black shale and interbedded gray shale containing shaly concretions and pyrite.
Devonian	Upper		Java	90-115	Greenish-gray to black shale and some interbedded limestone and zones of calcareous nodules. Small masses of pyrite occur in the lower part.
Devonian	Upper		West Falls	400-520	Black and gray shale and light-gray siltstone and sandstone. The lower part is petroliferous. Throughout the formation are numerous zones of calcareous concretions, some of which contain pyrite and marcasite.
Devonian	Upper		Sonyea	45-85	Olive-gray to black shale.
Devonian	Upper		Genesee	10-20	Dark-gray to black shale and dark-gray limestone. Beds of nodular pyrite are at base.
Devonian	Middle	Hamilton	Moscow Shale	12-55	Gray, soft shale.
Devonian	Middle	Hamilton	Ludlowville Shale	65-130	Gray, soft, fissile shale and limestone beds at top and bottom.
Devonian	Middle	Hamilton	Skaneateles Shale	60-90	Olive-gray, gray and black, fissile shale and some calcareous beds and pyrite. Gray limestone, about 10 feet thick is at the base.
Devonian	Middle	Hamilton	Marcellus Shale	30-55	Black, dense fissile shale.
Devonian	Middle	Unconformity	Onondaga Limestone	108	Gray limestone and cherty limestone.
Silurian	Cayuga	Unconformity	Akron Dolomite	8	Greenish-gray and buff fine-grained dolomite.
Silurian	Cayuga	Salina	Bertie Limestone	50-60	Gray and brown dolomite and some interbedded shale.
Silurian	Cayuga	Salina	Camillus Shale	400	Gray, red, and green thin-bedded shale and massive mudstone. Gypsum occurs in beds and lenses as much as 5 feet thick. Subsurface information indicates dolomite (or perhaps, more correctly, magnesian-lime mudrock) is interbedded with the shale (shown schematically in section). South of the outcrop area, at depth, the formation contains thick salt beds.
Silurian	Niagara		Lockport Dolomite	150	Dark-gray to brown, massive to thin-bedded dolomite, locally containing algal reef and gypsum nodules. At the base are light-gray limestone (Gasport Limestone Member) and gray shaly dolomite (DeCew Limestone Member).
Silurian	Niagara	Clinton	Rochester Shale	60	Dark-gray calcareous shale.

Figure 2.--Bedrock units of the Erie-Niagara basin.

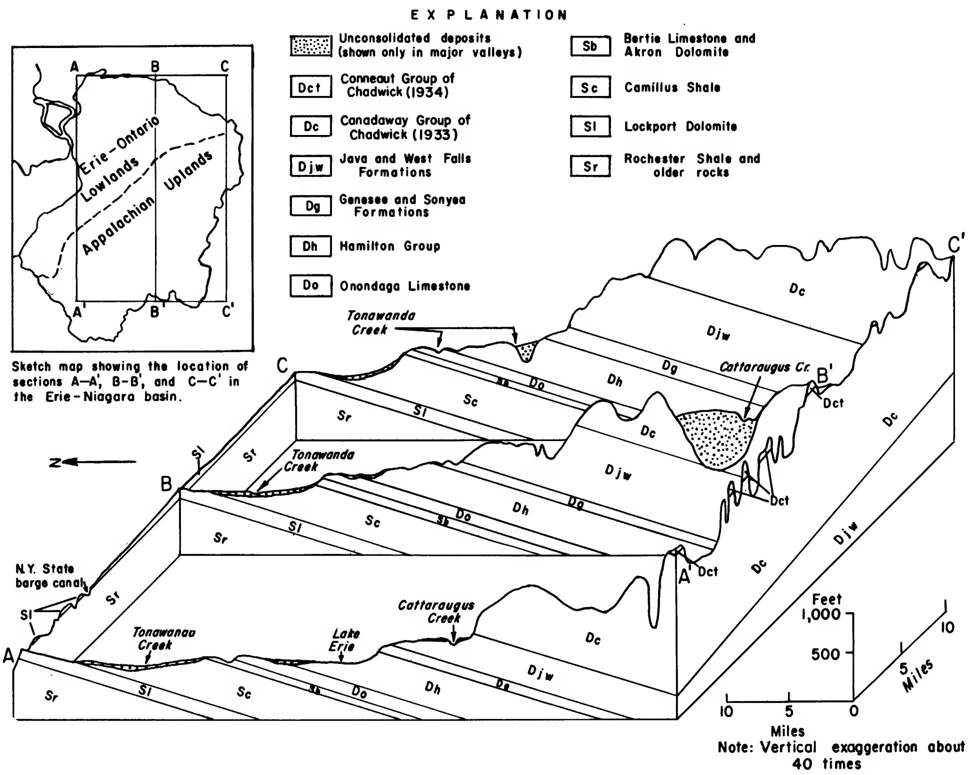


Figure 3.--Fence diagram of part of the Erie-Niagara basin.

OCCURRENCE OF GROUND WATER

Ground water is commonly thought of as water that comes from wells and springs. This definition makes the essential point and distinguishes ground water from other subsurface water. Water wells provide the most easily obtainable information on ground-water resources, but the information can be misleading. A casual inspection of a body of random data on wells in the area may lead to the notion that ground water occurs in a haphazard fashion. For example, it is apparent from the data in table 6 that wells vary greatly in depth and yield. Depths range from about 10 to 500 feet, and yields from a few gallons per day to more than 1,000 gpm. What is more, wells of large yield are interspersed with wells of low yield. A more careful study of the data shows that some of the variations in well characteristics reflect differences in well construction rather than in the availability of ground water. A carefully planned and constructed public-supply well gives a more complete picture of water availability than does a driven well constructed for lawn watering. But after accounting for variations in well construction, profound differences in the availability of ground water are still apparent. These differences arise mainly from the geologic and topographic features of the basin.

Ground water occurs in the saturated zone of the earth's crust. The water in the saturated zone (ground water) fills the interconnected openings in the rocks and is under hydrostatic pressure. As shown in figure 4, ground water will flow through the zone of saturation following a course that takes it from a point of higher head to a point of lower head. In this way water entering the ground on a hill may discharge through a spring on the side of the hill, into a nearby stream, or into a river many miles away. When the water standing in a well is pumped out, the head (water level) in the well is lowered. Water from the saturated zone can then move toward the well in the same manner it moves toward points of natural discharge. Where the saturated zone is not overlain by impermeable materials, its upper surface is the water table. The depth to the saturated zone in the area varies from 0 feet in some swamps to possibly more than 75 feet along the edges of some glacial terraces.

The unsaturated materials over the saturated zone make up the zone of aeration, the zone in which the openings are partly filled with air (fig. 4). Water in the zone of aeration is held to the walls of the openings by molecular forces. This prevents the free movement of water in the zone of aeration; water in this zone drains slowly downward but not laterally. Wells and springs, therefore, cannot obtain water from the zone of aeration. The zone is important, however, because water must pass through it to reach the saturated zone.

The unconsolidated deposits and the bedrock differ markedly in the types of water-bearing openings they contain (fig. 4). The unconsolidated deposits are composed of grains packed together with open spaces, or pore spaces, between the grains. Water truly permeates the unconsolidated deposits because it can fill the myriad of tiny pore spaces between the grains.

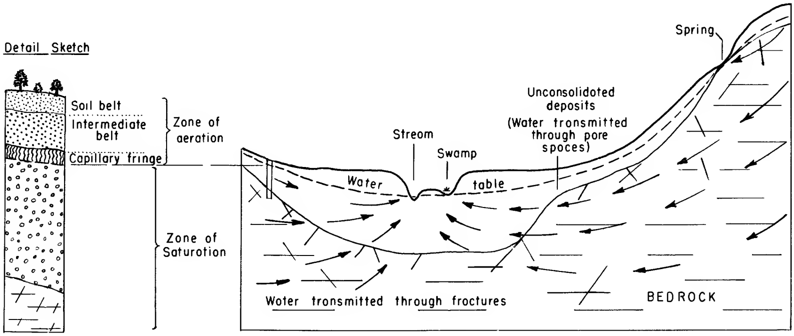


Figure 4.--Occurrence of ground water. Arrows show direction of ground-water movement.

The sediments composing the bedrock initially also contained pore spaces, but these pores were closed when the sediments were compacted and cemented. A solid piece of rock from any of the bedrock units in the area is nearly or completely impermeable. But in each of the units, masses of rock have separated along fractures. These fractures transmit ground water through the bedrock.

OCCURRENCE OF WATER IN BEDROCK

The principal water-bearing fractures in the bedrock are joints which are regularly arranged. They are caused by geologic forces acting through broad areas and occur in sets, all the joints of which are roughly parallel. In the Erie-Niagara basin, the rocks are cut typically by two sets of vertical joints. One set trends northeast and the other northwest, forming diamond-shaped patterns at the surface. These vertical joints are spaced from a few feet to perhaps 30 feet apart and may be 50 feet to a few hundred feet long at the surface. More important joints, however, are the horizontal ones that are parallel to the bedding planes of the rocks. These joints develop along planes of weakness between adjacent layers of rocks. The evidence suggests that bedding-plane joints are the principal water-bearing openings in the bedrock.

Faults, which are fractures along which adjacent masses of rock have been offset, may also provide openings for ground-water circulation. A fault trending south through Batavia is the only major one known in the area (pl. 2). However, other faults may exist but are not recognized because they are covered by the glacial deposits.

Still another factor in regard to the water-bearing openings in bedrock must be considered. Some of the rocks are relatively soluble in water; some are essentially insoluble. Ground water circulating through joints removes soluble material by dissolving it, thereby widening the joints and making them still better conduits for ground water. Such solution has enhanced considerably the water-bearing properties of the more soluble rocks.

On the basis of lithology and water-bearing properties, the numerous bedrock units in the Erie-Niagara basin can be divided into two groups: soluble bedrock and shale bedrock. Of the two, the soluble rocks are an important source of water, whereas the shale yields only small supplies.

The Lockport Dolomite, Camillus Shale, Bertie Limestone, Akron Dolomite, and Onondaga Limestone (fig. 2 and pl. 2) are composed of rock materials that are relatively soluble in water. Subsurface water has been relentlessly quarrying the rocks by solution, particularly during the 10,000 years or so since the ice sheet melted from the area. In more extensive and more weathered limestone terranes elsewhere, such as in Kentucky, this process has produced numerous caves and underground streams. In the Erie-Niagara basin, the same process is underway but has advanced only enough to widen considerably many of the water-bearing openings and to enhance the circulation of ground water.

Four of the five formations listed as soluble rocks are either limestone or dolomite. Limestone is composed mainly of the mineral calcite which is a natural form of calcium carbonate. Dolomite is composed of calcium-magnesium carbonate and is less soluble than limestone. Both rocks are attacked by acid. Water that percolates through soil generally dissolves carbon dioxide and, therefore, becomes a weak acid. The initial acidity gives ground water much of its ability to dissolve the carbonate rocks.

The fifth formation, the Camillus Shale, seems out of place listed with dolomite and limestone as a soluble rock. Shale is not by any stretch of the imagination a soluble rock. But the Camillus Shale is unique among the shale formations of the area because it contains a large proportion of gypsum, a calcium-sulfate mineral which is even more soluble than limestone. The gypsum is interbedded with and even diffused through the shale.

Except where removed by erosion, the soluble rocks lie one above another with the Lockport Dolomite on the bottom, the Camillus Shale in the middle, and the Bertie, Akron, and Onondaga on top. For hydrologic purposes the Bertie, Akron, and Onondaga can be considered to form a single aquifer or water-bearing unit, which is called the limestone unit. (These three formations are distinct in a geologic sense but not in a broad hydrologic sense.) All the soluble rocks dip (are inclined) southward at about 40 feet to the mile.

The soluble rocks are bounded top and bottom by shale formations of much lower permeability. The Rochester Shale is at the base of the Lockport Dolomite, and the Marcellus Shale overlies the Onondaga Limestone.

The water-bearing properties of the soluble rocks developed to a large degree in response to the composition of the rocks (lithology) and the primary sedimentary structures (bedding). The soluble rocks are composed of dense materials that are innately not water bearing. These rocks transmit water only through fractures and solution openings. The nature of the water-bearing openings can be studied both from exposures of the rocks and from data on wells. How good any unit is as a source of water can be judged from records of wells. All of these hydrologic properties and characteristics for each rock unit will be discussed in the following sections.

LOCKPORT DOLOMITE

Bedding and lithology

The lowest aquifer, the Lockport Dolomite, consists mainly of gray, fine- to coarse-grained dolomite. The Gasport Limestone Member near the base of the formation is a light-gray limestone. The thickness of the Lockport is approximately 150 feet. A general summary of the lithology and thickness of the lithologic units is given in figure 5.

The rock units within the Lockport are bedded and dip southward in the study area at 35 to 40 feet per mile. In the extensive exposures Johnston (1964, p. 22) observed in excavations for the Niagara Power Project at Niagara Falls, the beds ranged generally from 1 inch to 3 feet in thickness. In some zones, beds were only 1/4 inch thick. On the other hand, a few massive beds are as much as 8 feet thick at places. The beds thicken and thin laterally. Approximate positions of some fairly persistent zones of massive and thin beds are shown in figure 5 by the widths of the bands of lithologic symbols. The bedding planes are flat except at the few places where they curve over ancient reefs in the upper part of the formation. These reefs are massive (nonbedded) structures as much as 50 feet across and 20 feet thick. Nodules of gypsum 1/2 to 5 inches across are common in the dolomite. Particles composed of the sulfide minerals of zinc, lead, and iron are disseminated through the rock.

Water-bearing openings

With respect to water-bearing openings in the Lockport Dolomite near Niagara Falls, Johnston's (1964) report may be considered a type study for rocks of this sort. Johnston found that bedding-plane joints are the principal water-bearing openings in the Lockport. Vertical joints and voids from which gypsum nodules were dissolved are minor water-bearing openings.

Water-bearing bedding-plane joints can occur at any stratigraphic horizon in the Lockport Dolomite. However, those that are persistent commonly occur in zones of thin beds overlain by thick or massive beds. Johnston identified seven persistent water-bearing joints or zones (several closely spaced joints) in the Niagara Falls area. (His findings are summarized in figure 5.) These joints are continuous for some miles, but they are not water

bearing everywhere. Where the joints are water bearing, they have been widened to some degree by the solution of rock by ground water. Some of the joints are open as much as 1/8 inch. Locally, solution along bedding joints has been great enough to cause the rock overlying the solution opening to settle.

The stratigraphic and hydrologic data for the Erie-Niagara basin are not sufficient to prove if Johnston's water-bearing bedding-plane joints extend beyond the Niagara Falls area. Well data and the examination of outcrops do indicate that at least similar sets of such joints transmit ground water in the Lockport Dolomite within the Erie-Niagara basin.

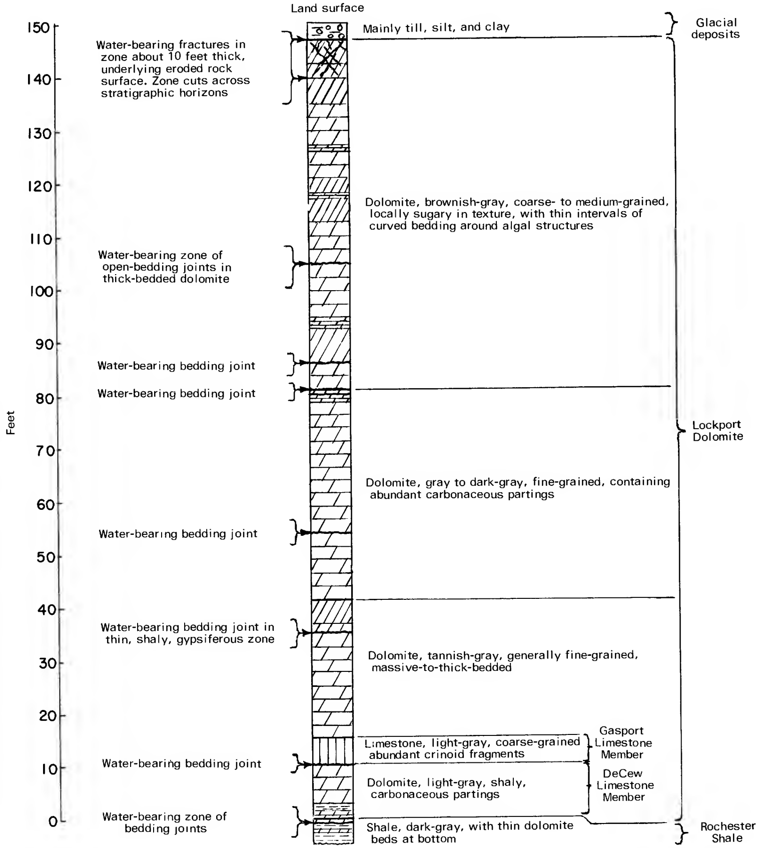


Figure 5.--Water-bearing zones in the Lockport Dolomite (adapted from Johnston, 1964).

In addition to the bedding-plane joints, a widespread water-bearing zone of highly fractured rock, perhaps 10 feet thick, lies at the top of the Lockport. This zone follows the upper surface of the rock in the outcrop area rather than a stratigraphic horizon and is hydraulically connected to the overlying glacial deposits.

A third zone of water-bearing openings is found where gypsum has been dissolved out of the Lockport Dolomite. The gypsum occur as nodules that are locally concentrated along bedding planes. Although gypsum forms a dense, impermeable rock, it is far more soluble than the enclosing rocks, whether shale, dolomite, or limestone. Only those gypsum zones actually exposed to circulating ground water can be widened by solution. The gypsum must be in contact with open fractures through which the water can move. If no open fractures exist, the gypsum is safe from being dissolved. Johnston (1964, fig. 8) observed a thin gypsum zone in the Lockport Dolomite which illustrates this fact. His water-bearing zone 3, a horizontal joint in a gypsiferous zone, was not open everywhere. (This is the zone about 35 feet above the base of the Lockport shown in figure 5.) Where the zone was closed to circulating water, the gypsum was intact.

Hydrologic characteristics

Although ground water moves through the soluble rocks toward Tonawanda Creek and its tributaries, the path of ground-water movement in each of the rock units is somewhat different. The water-bearing zones in the Lockport Dolomite receive water along the traces of their intersections with the surface or the overlying deposits. The water is discharged to small streams and swamps on the dip slope or flows into the Camillus Shale through the subsurface.

The zone of fracturing and solution that follows the upper surface of the soluble rocks is in hydraulic continuity with the glacial deposits. Water moves between this zone and the glacial deposits. Water enters the bedding joints where the joints come to the surface or where they intersect the glacial deposits or water-bearing fracture zone at the rock surface. Vertical joints also transmit some water but, at most places, they are not open to a significant degree. The occurrence of water at the gypsum mine portrayed in figure 6 indicates very restricted vertical circulation. Vertical joints are not present in the mine. Water finds its way through the roof of the mine only where roof bolts and cracks have intersected horizontal openings. Evidence was also presented by Johnston (1964, p. 29) to prove that horizontal joints in the Lockport Dolomite are not interconnected by vertical joints to any significant degree. Johnston was able to measure the head of water in various bedding joints in the Lockport. He found that the head declines in successively lower joints. The head differences are explained by the position of the joints and topography. The successively lower joints crop out at successively lower altitudes.

Hydraulic properties

The hydraulic properties of an aquifer are described by its coefficient of trasmissibility (T) and its coefficient of storage (S). The coefficient of transmissibility is a quantitative description of the rate at which an aquifer will transmit ground water. It is defined as the rate of flow, in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness, under a hydraulic gradient of 1 foot per foot at the prevailing temperature of the water. The coefficient of storage of an aquifer describes the properties of an aquifer in releasing water from storage. It is defined as the volume of water the aquifer releases or takes into storage per unit surface area per unit change in the head normal to the surface. The storage coefficients of the bedrock units vary mainly with the volume of the openings in the rocks, which, in turn, vary mainly with the solubility of the rocks. The aquifer constants (T and S) are necessary to compute the quantities of water that can be obtained from an aquifer, the effect of pumping on ground-water levels, and the most favorable spacing of wells.

Pumping tests should be performed to determine the constants where-ever ground water is to be intensively developed. The constants already determined in the Erie-Niagara basin show that the soluble rocks generally have moderate to high coefficients of transmissibility and low coefficients of storage. This means that wells in these formations will produce moderate to large yields but that the cones of depression around the wells will develop rapidly and extensively. (Cone of depression is defined as the depression in a water table or piezometric surface caused by pumping.) However, in large-yield wells in north Buffalo and the Tonawandas that are pumped either continuously or for prolonged periods, the water levels are generally stable. The stable pumping levels indicate that the rocks receive recharge from streams. Temperature data for wells near the Niagara River also indicate that recharge is received from the river, as will be explained later.

For the Lockport Dolomite, Johnston (1964, p. 33) calculated a coefficient of transmissibility of 2,300 gpd (gallons per day) per foot from data collected during dewatering of an 18,000-foot long conduit near Niagara Falls. This probably is a representative figure for the Lockport because of the extent of rock involved. Pumping tests on four wells in the Niagara Falls area gave transmissibilities of 300 to 1,000 gpd per foot and coefficients of storage of 0.00001 to 0.0003. The small transmissibility of 300 gpd per foot and small coefficient of storage of 0.00001 apply to the lower part of the Lockport.

Yields of wells

The data on yields of wells in the soluble rocks should be interpreted from the standpoint of hydrology and geology. They are not suitable for statistical treatment.

Many domestic-supply wells penetrate from 1 foot to a few feet into the soluble rocks and produce small but adequate yields. On the other hand, industrial wells that were intended to produce large supplies of water give a truer picture of the water-supply potential of the rocks. Data on industrial wells show that the Camillus Shale will yield as much as 1,200 gpm and the limestone unit as much as 300 gpm and probably more. But the data also show that the rocks produce low yields at places. This is shown by such wells as 301-848-1 which was drilled to obtain a large supply for an industry but which yielded only 30 gpm. The water-bearing zones obviously are unevenly distributed through the rocks. Factors that control the occurrence of the water-bearing zones cannot be evaluated at the present time to the extent necessary to predict exactly where the zones occur.

The Lockport Dolomite is the least productive unit of the soluble rocks. Within the Erie-Niagara basin yields of wells in the Lockport range from about 4 to 90 gpm. Depth of the wells range from 20 to 70 feet. Most of the deeper wells were drilled where the depth to bedrock is greatest. Domestic-supply wells generally are finished in the fracture zone at the rock surface or in a bedding joint within the uppermost 30 feet of the rock. It is usually not necessary to drill deeper into the Lockport if only a small supply is needed.

Drilling deeper in an attempt to intersect additional bedding-plane openings at depth would provide higher yields but, generally, at the expense of lower water levels and therefore higher pump lifts. Johnston (1964) collected data on a much larger number of wells along the outcrop belt of the Lockport Dolomite than were inventoried in the Erie-Niagara basin. He found that wells drawing water from the lower 40 feet of the Lockport (the northern part of the outcrop area) yield from 1/2 to 20 gpm and have an average yield of 7 gpm. Wells finished in the upper part of the Lockport (the southern part of the outcrop area) yield from 2 to 110 gpm and have an average yield of 31 gpm. Yields of as much as 50 or 100 gpm are possible from the Lockport in the Erie-Niagara basin but would be exceptional.

CAMILLUS SHALE

Bedding and lithology

The Camillus Shale lies above the Lockport Dolomite and crops out to the south of where the dolomite is exposed. Exposures of the Camillus Shale are rare in the Erie-Niagara basin because of the low relief of the outcrop area and the cover of glacial deposits. Geologists who have studied the Camillus in the study basin agree that it consists mostly of gray shale. (For example, see Buehler and Tesmer, 1963, p. 29-30.) Subsurface data, on the other hand, indicate that a considerable amount of gray limestone and dolomite is interbedded with the shale. Along with these carbonates, gypsum comprises a significant part of the Camillus Shale. Some of the gypsum beds are as much as 5 feet thick. Gypsum also occurs in the Camillus as thin lenses and veins. Table 1,

Table 1.--Log of a gypsum-mine slope near Clarence Center

(Site 300-839-A)

Log	Depth below land surface (feet)
Topsoil, subsoil, gravel and clay........................	0-25.5
Soft gray limestone mixed with clay......................	25.5-27.5
Soft dark-gray limestone.................................	27.5-29.5
Soft shaly limestone, thin bedded........................	29.5-38.0
Crushed dark-gray limestone interbedded with 2-inch seams of brown limestone...............................	38.0-40.8
Dark-gray limestone interbedded with seams of gypsum 1 1/2 to 3 inches thick................................	40.8-43.6
Hard gray limestone interbedded with thin streaks of gypsum 1/8 to 1/2 inch thick.........................	43.6-45.1
Soft gray limestone......................................	45.1-49.1
Hard gray limestone interbedded with thin streaks of gypsum..	49.1-52.1
Hard gray limestone......................................	52.1-57.6
Gypsum...	57.6-58.3
Brown limestone..	58.3-59.3
Gray limestone...	59.3-61.3
Soft, crumbly green-gray material (shale)................	61.3-64.3
Mottled rock rich in gypsum..............................	64.3-65.1
Soft brown limestone.....................................	65.1-65.7
Cap rock -- hard dark-gray limestone.....................	65.7-66.8
Soft shaly material......................................	66.8-66.9
Gypsum...	66.9-71.4

which is a log compiled during construction of a mine slope, illustrates the occurrence of gypsum and the predominance of carbonate rocks in some parts of the Camillus.

Though the Camillus dips southward at approximately 40 feet to the mile, the dip is not uniform. Gypsum miners say the formation "rolls," to describe the gentle folding of its beds. The formation is marked by broad, low folds with amplitudes of a few feet and spacings of a few hundred feet between crests. The fold axes generally are east-west.

Water-bearing openings

The extensive beds of gypsum make the Camillus Shale unique among the shale formations of the basin. The importance of the gypsum lies in its solubility; gypsum is far more soluble than the enclosing rocks, whether shale, dolomite, or limestone. Where gypsum has been dissolved, openings exist for the passage and storage of water.

The effect of the solution of gypsum on the water-bearing properties of the Camillus Shale (and other rocks) can be readily appreciated. Where the topmost beds of the Camillus crop out at the base of the falls of Murder Creek at Akron, the Camillus seems to be an impermeable shale. If one judged the water-bearing properties of the Camillus on the basis of this outcrop alone, he would be wrong. Yields of water wells and drainage into gypsum mines prove that large volumes of water do move through the Camillus.

Clues to the nature of the water-bearing openings in the Camillus can be obtained by considering some of the circumstances where large volumes of water were obtained. About 1885, the Buffalo Cement Company located a 4-foot thick bed of gypsum only 43 feet below land surface by test drilling in Buffalo on Main Street near Williamsville. A shaft was sunk with the intention of beginning a subsurface mining operation, but when the gypsum was struck the shaft was flooded with ground water. The report is that "..... a pump with a capacity of 2,000 gallons per minute failed to make any impression upon it [the water] and the attempt was abandoned" (Newland and Leighton, 1920, 209-210).

In 1964, a gypsum mine near Clarence Center received an unexpected inflow of ground water. Several hundred gallons of water per minute continuously enters the mine at a place about midway down the entry slope. This water is pumped out by a drainage system diagrammatically shown in figure 6. Ordinarily, only small seeps occur in the remainder of the mine from roof bolts and small cracks in the roof. At a distance of more than a mile from the entry slope, the working face intersected an unplugged drill hole. Water poured into the mine at an alarming rate until the hole was plugged with much effort.

Large-yield wells, such as those at Tonawanda and North Tonawanda, obtain water from thin intervals of gypsum-bearing rock. The gypsum in the Camillus Shale obviously is related to the occurrence of large quantities of water. Gypsum is a highly soluble mineral and is

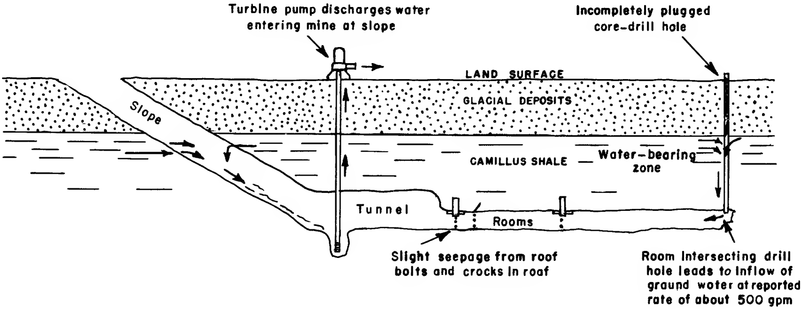


Figure 6.--Occurrence of ground water in the Camillus Shale at a gypsum mine near Clarence Center.

dissolved by circulating ground water faster than are the enclosing rocks. Very likely the openings in the Camillus that yield copious amounts of water were formed by the solution of gypsum by ground water. The water-bearing zones are mainly horizontal because most of the gypsum occurs in horizontal beds and thin zones of gypsiferous shale and dolomite. Only those gypsum zones actually exposed to circulating ground water can be widened by solution. The gypsum must be in contact with an open fracture through which the water can move. If no open fracture exists, the gypsum cannot be dissolved. The occurrence of ground water at the gypsum mine shown in figure 6 is a further illustration. The 4 1/2-foot thick bed that is mined at a depth of 66.9 feet (table 1) is dry because of the lack of vertical fractures to transmit water to it.

The solution-widened water-bearing zones occur at various depths and stratigraphic horizons in the Camillus. The existence of such zones is borne out by well data. For instance, wells 303-850-1 and -2 are 90 feet apart and obtain water from the same 2- to 3-foot thick zone at a depth of 67 to 68 feet. Such zones may be continuous for as much as 1 or 2 miles but information is not available on the extent of individual zones. The gypsum occurs principally in lenticular beds. The thicker beds may be 3 or 4 miles in lateral extent. The thinner beds can be expected to be much smaller in extent.

A zone of fracturing and solution extending several feet below the rock surface yields relatively small but sufficient water supplies for domestic use. This zone appears to be present throughout the area and is unrelated to stratigraphic position.

Hydrologic and hydraulic characteristics

The Camillus Shale forms a low topographic trough split down the axis by Tonawanda Creek. Ground water that enters the formation discharges mainly to the creek. Little water is discharged to the small, barely incised streams on the Camillus. These streams are dry much of the year.

Coefficients of transmissibility given in table 2 were computed for the Camillus Shale on the basis of specific capacities of wells penetrating a considerable thickness of the aquifer, by the method described by Walton (1962, p. 12-13).

Table 2.--Specific-capacity tests of wells finished in the Camillus Shale

Well number	Pumping rate (gpm)	Duration of pumping (hours) e: estimated	Drawdown (feet)	Specific capacity (gpm/ft)	Coefficient of transmissibility (gpd/ft)
a/ 258-853-1	1,090	e8	53	21	40,000
-2	90	--	22	4	7,000
258-855-1	500	e8	17	29	55,000
-2	1,000	e8	26	38	70,000
-3	1,500	e8	38	39	70,000
303-850-1	700	24	10	70	--
-2	660	e8	8	83	--

a/ Well also penetrates water-bearing zone in Lockport Dolomite.

The large specific capacities of wells 303-850-1 and -2 probably result in part from recharge induced from Sawyer Creek. Measurements of recovery of water levels in well 303-850-1 were made when well 303-850-2 was shut down after a year of continuous pumping. From these data, a coefficient of transmissibility of about 80,000 per foot and a coefficient of storage of 0.025 were computed. The computed transmissibility is about half the transmissibility that would have been indicated from specific capacity if recharge were not induced from Sawyer Creek.

Yields of wells

The Camillus Shale is by far the most productive bedrock aquifer in the area. Except in the vicinity of Buffalo and Tonawanda, where industrial wells produce from 300 to 1,200 gpm, no attempt has been made to obtain large supplies from the formation. However, the inflow of water to gypsum mines near Clarence Center and Akron indicate that large supplies are not necessarily restricted to the Buffalo and the Tonawanda area. Two examples of large flows of water encountered in gypsum mining have already been mentioned. Pumpage from gypsum mines near Clarence Center (including the mine mentioned previously) is substantial. The water pumped is discharged to Got Creek. On July 2, 1963, the creek had a flow of 2.1 mgd (million gallons per day) about half a mile downstream from the mines, that was due almost entirely to the pumpage. Water for industrial use is pumped from a flooded, abandoned gypsum mine at Akron. This pumpage, at a rate of 500 to 700 gpm, has had no appreciable effect on the water level in the mine.

Probably the larger solution openings are most common in discharge areas near Tonawanda Creek and its tributaries and near the Niagara River; the flow of ground water becomes concentrated as it approaches the streams to which it discharges. Other discharge areas, such as low-lying swampy areas and headwaters of small streams that have perennial flow, are likely places to drill wells.

LIMESTONE UNIT

Bedding and lithology

The term "limestone unit" in this report is applied to a sequence of limestone and dolomite overlying the Camillus Shale. The limestone unit includes the Bertie Limestone at the base, the Akron Dolomite, and the Onondaga Limestone at the top. The lithology and thickness of these units are shown in figure 7. The Bertie Limestone and the Akron Dolomite are Silurian in age and are separated from the overlying Onondaga Limestone of Devonian age by an unconformity or erosional contact.

The Bertie Limestone is mainly dolomite and dolomitic limestone but contains interbedded shale particularly in the thin-bedded lower part of the formation. The middle part is brown, massive dolomite, and the upper part is gray dolomite and shale whose beds are of variable thickness. The total thickness of the formation is about 55 feet (Buehler and Tesmer, 1963, p. 30-31).

The Akron Dolomite is composed of greenish-gray and buff dolomite beds varying from a few inches to about a foot in thickness. The upper contact of the Akron is erosional and is often marked by remnants of shallow stream channels. Thin lenses of sandy sediments lie in the bottoms of some channels. The thickness of the formation is generally between 7 and 9 feet (Buehler and Tesmer, 1963, p. 33-34).

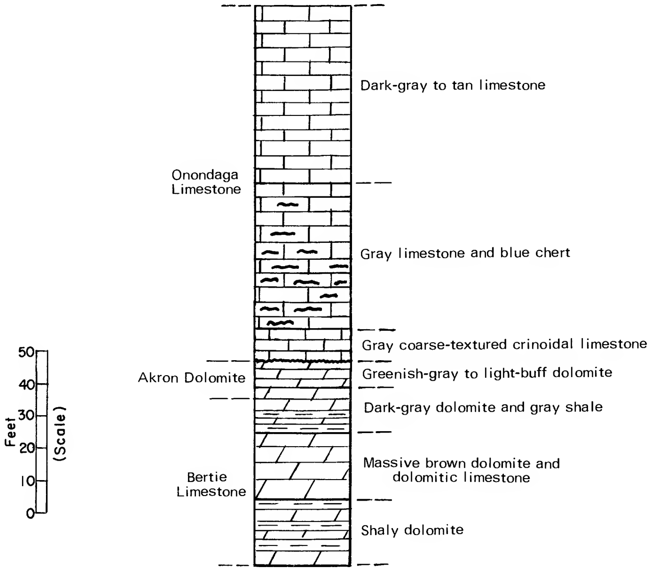


Figure 7.--Lithology of the limestone unit.

The Onondaga Limestone, about 110 feet thick, makes up the greatest thickness of the limestone unit. The formation consists of three members. The lowest member is a gray coarse-grained limestone, generally only a few feet thick. At places this member grades laterally into reef deposits which increases its thickness (Buehler and Tesmer, 1963, p. 35-36).

The middle member of the Onondaga is a cherty limestone. In some zones the chert exceeds the amount of limestone. The unit is probably 40-45 feet thick.

The upper unit is a dark-gray to tan limestone of varying texture and is probably about 50-60 feet thick.

Water-bearing openings

The limestone unit contains water-bearing openings that are similar to those of the Lockport Dolomite. Because the limestone unit is more soluble, however, solution widening of the openings appears to be more

pronounced. The types of water-bearing joints in the limestone can be seen at the falls of Murder Creek at Akron. Not all of the flow of Murder Creek plunges over the falls. A considerable part of the flow percolates into the limestone unit upstream from the falls and discharges from bedding joints both at the face and along the sides of the falls. The principal zones of discharge are at the base of the Bertie, and at a contact of a shaly zone and overlying thick-bedded dolomite 20 feet above the base.

The falls at Akron also illustrate in an exaggerated way the role of vertical joints. Water from Murder Creek percolates into the rock through solution-widened vertical joints before reaching the bedding-plane joints. The continuous and concentrated flow of water in the creek has widened the vertical joints to an unusual degree. Vertical joints are ordinarily very narrow. They probably are most effective in aiding the movement of water to the bedding joints where the bedding joints are close to the rock surface.

Locally, solution along bedding joints in the limestone unit has been great enough to cause the rock overlying the solution opening to settle. Settling of this type probably accounts for at least some of the small depressions in the outcrop belt of the Onondaga Limestone. A collapsed solution zone in the Onondaga Limestone discharges a large volume of water into a quarry (257-840-A) near Harris Hill. About 3,000 gpm is pumped from the quarry, and most of the water is reported to come from the solution zone.

The limestone unit is cut by a fault on the east side of Batavia. Faults cutting limestone are likely to cause shattering along the fault and, thus, create a permeable water-bearing zone.

Hydrologic and hydraulic characteristics

The limestone unit is similar to the Lockport Dolomite in structure. However, its hydrology is different. The limestone unit is cut transversely by Tonawanda Creek and its major tributaries. Small tributaries flow across it in northerly and westerly directions. The limestone unit receives water in the interstream areas by percolation into joints. The water is discharged laterally to the streams and at places along the north-facing scarp or enters the Camillus Shale at depth.

The coefficient of transmissibility of the limestone unit probably ranges from about 300 to 25,000 gpd per foot. Specific capacity data are given in table 3. Drillers' reports indicate high transmissibilities for the limestone unit in Williamsville which probably arise from relatively intense circulation of ground water near Ellicott Creek. The coefficients of transmissibility given in table 3 were computed from specific capacity data by the method described by Walton (1962, p. 12-13).

Table 3.--Specific-capacity tests of wells finished in the limestone unit

Well number	Pumping rate (gpm)	Duration of pumping (hours)	Drawdown (feet)	Specific capacity (gpm/ft)	Coefficient of transmissibility (gpd/ft)
252-852-1	85	34	7	12.1	25,000
-2	30	--	17	2	4,000
255-848-1	130	--	10	13	25,000
255-850-1	180	6	45	4	8,000
259-824-1	100	8	30	3.3	6,000
-2	100	8	12	8.3	15,000
300-824-1	104	8	28	3.7	7,000

The coefficient of storage of the limestone unit is probably between those of the Lockport Dolomite and the Camillus Shale. The storage coefficients of these three units vary mainly with the volume of the openings in the rocks which, in turn, vary with the solubility of the rocks. Limestone is more soluble than dolomite but less soluble than gypsum. Storage coefficients in the limestone unit should, therefore, be somewhat higher than those of the Lockport Dolomite but somewhat lower than those of the Camillus Shale.

Yields of wells

The limestone unit is more productive than the Lockport. A number of large-yield wells in Buffalo, Cheektowaga, Williamsville, Pembroke, and Batavia are finished in the limestone unit and indicate that yields of 300 gpm and possibly more can be obtained. Like the Lockport Dolomite, the yields of wells in the limestone unit range through a broad spectrum. However, the more productive wells in the limestone unit are relatively abundant when compared to those in the Lockport. Of significance also is that three wells half a mile apart drilled for an industrial firm near Pembroke, each sustained a discharge of about 100 gpm (table 6, wells 259-824-1, -2, and 300-824-1). These three wells indicate that such yields are available in some areas.

SHALE

Bedding and lithology

The Marcellus Shale and all overlying formations are distributed through the southern half of the Erie-Niagara basin. They are predominantly shale but include a few thin limestone members at various stratigraphic positions (fig. 2). Thin beds of fine-grained sandstone are also interbedded with the shale in the upper part of the section. The rocks dip southward at about 40 feet per mile. They underlie the upland part of the basin and also a broad plain along Lake Erie in the southern part of the basin. Streams eroded deep valleys in the uplands prior to glaciation. The rocks were further eroded during glaciation and later these valleys were partly filled with stratified glacial deposits and the hills were veneered with till. The rocks on the lake plain are thinly covered with till and clay. In postglacial time Cattaraugus and Eighteenmile Creeks, where they cross the lake plain, cut spectacular gorges in the shale.

Water-bearing openings

The shale formations are cut by both vertical and bedding-plane joints along which are hairline openings. Locally, openings along thin limestone beds may be widened by solution. An important feature of the shale is a discontinuous zone of fracturing that follows the upper surface of the rock. In places, this zone consists only of shallow tension cracks caused by the movement of glacial ice over the rock. At other places, the zone is as much as 10 feet thick and consists of crumpled and broken rock. Some exposures show convoluted beds interfolded with glacial deposits.

Hydrologic characteristics

Water enters the shale almost exclusively by percolation from the overlying glacial deposits in interstream areas. Generally, the water table or top of the saturated zone lies in the glacial deposits above the shale. The water table lies within the shale only where the glacial deposits are absent or thin. The fracture zone at the top of the rock is directly connected to the glacial deposits and, therefore, is most advantageously positioned to receive water. At places, the fracture zone is overlain by a thin section of coarse-grained till which is, in turn, overlain by clayey till of much lower permeability. The coarse-grained till and fracture zone then act as a single water-bearing zone. The vertical and bedding joints, which extend into the shale at depth, receive water where they intersect the fracture zone along the top of the rock or intersect the overlying glacial deposits. The joints are thin and widely spaced. The shale at depth, therefore, has a much lower permeability than the fracture zone at the top of the shale.

Yields of wells

The shale formations generally yield only small supplies of water to wells. Individual wells provide adequate and dependable supplies for numerous homes and farms in the area. Yields of as much as 40 gpm are obtained from the Hamilton Group, probably because it contains limestone with openings that have been enlarged by solution. Elsewhere, the maximum yields of wells are generally 10 to 15 gpm from the fracture zone. If the fracture zone is absent, water is obtained from joints deeper in the rock and the yields of wells are much smaller. The small number of applicable data in table 6 indicate that the yields of wells drawing from the deeper fractures range from 1 to 7 gpm. However, dry holes or wells with inadequate yields are not uncommon and are not restricted to any stratigraphic unit or geographic area. The data are sparse by which to study the relationship of topography to yields. It does appear that the wells drilled in valleys, particularly if the shale is overlain by thick unconsolidated deposits, have somewhat larger yields than those wells on hills.

OCCURRENCE OF WATER IN UNCONSOLIDATED DEPOSITS

The unconsolidated deposits overlie the bedrock units previously discussed and consist of a variety of granular material. The bulk of the unconsolidated deposits are glacial in origin and include till, lake deposits, and sand and gravel deposits. The materials laid down since glaciation are thin and consist of alluvium and swamp deposits.

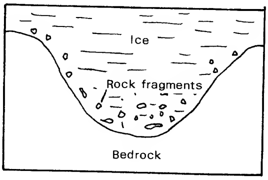
The deposits vary in their hydrologic characteristics because of differences in their lithology and thickness and because of their distribution and spatial relationships to one another. Plate 3 is a geologic map showing the division of the unconsolidated deposits into several groups on the basis of their origin. The distribution of these groups at the surface is readily apparent from the map. An understanding of the geologic processes that formed the deposits allows their subsurface distribution to be inferred. The map, therefore, can be read in three dimensions through proper interpretation.

An explanation of the origin and general features of the several types of deposits is given in figure 8. When the ice sheet advanced over the area, the ice tore and abraded the bedrock surface. The hills were somewhat reduced and rounded and the valleys were deepened. Some of the rock material eroded from the bedrock was redeposited by the ice and forms the poorly sorted mantle material that is called till (fig. 8A). Eventually, the ice began to wane with a change in climate. As the amount of snow nourishing it decreased, the ice sheet thinned. It had difficulty maintaining flow over rough topography along its marginal zone. The margin became scalloped, and some marginal zones grew so thin that they stagnated. These zones separated from the ice sheet and wasted away in place.

The sequence of deposition in an upland valley during retreat generally followed a particular order. A temporary valley was formed between the wasting ice and the rock wall of the valley. Melt water from the ice sheet, which at times of rapid melting was released in enormous quantities, flowed through the valley away from the retreating ice sheet. The melt water carried a heavy load of sediment washed out of the ice. It deposited sediment, mainly sand and gravel, and began to fill up the valley. This type of sand and gravel deposit is an ice-contact deposit (fig. 8B). In southward drained valleys, ice-contact deposits could form at low levels, even in the valley bottoms. In northward drained valleys, because of the divide to the south, the ice-contact deposits could form only high on the sides of the valley above the level of melt-water lakes impounded to the level of the spillway over the divides.

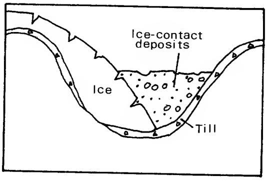
As the ice sheet melted back, a lower outlet for the melt water was uncovered. The melt-water stream was diverted from the ice-contact deposit. As the stagnant ice mass bordering the ice-contact deposits continued to melt away, the sand and gravel held up by the ice mass subsided toward the center of the valley. A lake formed in the open area left by the ice as it melted (fig. 8C). In a southward drained valley, the lake would be caused by a dam of earlier glacial deposits across the valley, perhaps part of the ice-contact deposits. In a northward drained valley, the lake would be formed between the divide to the south and the ice sheet to the north. Fine-grained sediments (clay, silt, and fine sand) settled out

A



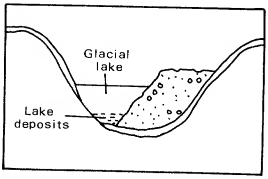
Ice advances over area and gathers load by eroding bedrock. Later, at the base of the ice, rock fragments are deposited to form till. (See B)

B



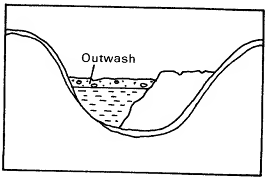
Ice begins to melt. Sand and gravel (ice-contact) deposits are laid down in a temporary valley between ice and valley wall.

C



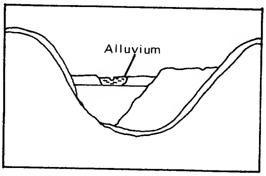
Stagnant ice melts. Ice-contact deposits slope toward center of valley. A glacial lake forms in which clay and silt accumulate.

D



Glacial lake is filled with sediment or is drained. Glacial streams flow over surface of lake deposits and lay down sand and gravel deposits.

E



Recent stream cuts into glacial deposits and lays down alluvium consisting of silt, sand and gravel.

Figure 8.--Origin of unconsolidated deposits.

in the lake and gradually filled it (fig. 8D).

Eventually the lake deposits built up to the threshold of the dam, or the dam was cut away by the water spilling over it, or the ice sheet retreated northward opening up the valley. Streams could then flow over the surface of the lake deposits and lay down a second sand and gravel deposit, an outwash deposit (fig. 8D). The sources of the stream waters were the wasting ice sheet (particularly so in southward drained valleys), small masses of wasting ice remaining in tributary valleys, and precipitation. The thickest and most extensive outwash deposits were formed in southward drained valleys and in zones peripheral to the ice sheet. With time, the ice sheet retreated still farther northward, the glacial streams ceased to flow, and glacial deposition came to an end.

As the ice sheet retreated farther north, the climate more nearly approached that of the present. A drainage system developed in response to precipitation. Streams began to incise channels into the deposits. Vegetation took hold as the weather warmed and helped stabilize the slopes. In time, with a change in regimen, the streams began to lay down alluvium (fig. 8E).

The sequence of events discussed above and shown in figure 8 is generalized. Nevertheless, it is useful in understanding the occurrence of the unconsolidated deposits, particularly in valley areas where they constitute an important source of ground water. In the following sections the lithology and water-bearing characteristics of each of the major types of deposits in the Erie-Niagara basin will be discussed.

TILL

As shown in plate 3, till is the most widespread of all the unconsolidated deposits in the Erie-Niagara basin. Till is essentially a nonsorted material whose character depends principally upon the types of rocks over which the ice passed and the vigor with which the ice crushed and abraded the rock. Till overlying the shale is dark gray and clayey or silty. In some areas, mainly on hillsides and terraces south of Cattaraugus Creek, part of the till is stony material. Till on the soluble rocks is light red and silty; in some morainic ridges it is mostly fine sand.

Thickness of the till varies considerably from a thin cover of 2 or 3 feet to more than 200 feet along the divides between Cattaraugus Creek and the northwestward flowing streams, such as Tonawanda, Buffalo, and Eighteenmile Creeks. On flat terraces mapped as till in Buttermilk Creek valley, the stony till is as much as 30 feet thick.

Only small supplies of water are available from till. The permeability of till is so small that wells with large wall areas are required to obtain even small supplies. This requirement for a large wall area is met by digging large-diameter wells.

LAKE DEPOSITS

Lake deposits consist of horizontally bedded clay, silt, and sand. They form a thin skin over till and bedrock in the Erie-Ontario Lowlands, but reach thicknesses of 300 feet or more in some valleys in the uplands. Thick sequences of clay (such as penetrated by well 229-842-1 near Springville) are so impermeable as to yield no water to wells. The lake deposits also contain thick sections of water-bearing fine sand in the major valleys of the Appalachian Uplands. This fine sand is called quicksand because it moves into wells. Small supplies can be developed from the fine sand by careful well construction, but usually these deposits are not utilized as sources of water.

GLACIAL SAND AND GRAVEL DEPOSITS

Glacial sand and gravel deposits include the ice-contact and outwash deposits shown in plate 3. In addition, deltaic deposits are present within the area. A prominent delta (lat 42°30', long 78°56') west of Collins, composed of sand and gravel, was built out from Clear Creek into a lake that occupied the Erie-Ontario Lowlands. Another delta (lat 42°50', long 78°34') was formed by Little Buffalo Creek, northeast of Marilla. These deltas are shown arbitrarily in plate 3 as ice-contact deposits. Deltaic deposits, presently concealed, probably interfinger with glacial lake deposits in the major valleys of the Appalachian Uplands where tributary streams deposited coarse-grained sediments in lakes. Subsurface data indicate deltaic deposits interfinger with lake deposits near the junction of Crow and Tonawanda Creeks south of the Attica State Prison. The sand and gravel deposits occur principally in the valleys of the Appalachian Uplands with only scattered, minor occurrences elsewhere. The relationship of the sand and gravel to the other unconsolidated deposits and to the bedrock is shown in figure 8. Where the deposits are thick and water bearing, they constitute the best aquifers found in the Erie-Niagara basin.

Lithology and thickness

The glacial sand and gravel deposits exhibit a variety of textures and sedimentary structures but they all are marked by stratification and a high degree of sorting. Characteristic of the deposits are horizontal beds of well-sorted sand, lenticular beds of cobble and boulder gravel, and scattered beds and lenses of open-work gravel. These various materials are interbedded in varying proportions, though boulder gravel is not present in most outwash deposits.

The deposits form thick fills in valleys of the upland section. In the valley bottoms the saturated thickness of the deposits exceeds 100 feet at many places. Thick deposits underlying terraces along the valley walls are to a large extent above the saturated zone. Buried sand and gravel deposits 10 to 40 feet thick underlie lake deposits in some valleys.

The thickness of the sand and gravel deposits can be inferred from the surficial geologic map (pl. 3) and the data on wells (table 6). The sand and gravel mapped as ice-contact deposits extends downward to till or bedrock. Till forms only a thin cover on the bedrock in most valleys, so the depth to bedrock can be assumed to be the thickness of the ice-contact deposits. The sand and gravel deposits mapped as outwash, on the other hand, are generally thin and overlie lake deposits in most valleys. The outwash deposits are thinnest wherever lake deposits are mapped in narrow bands along the edge of outwash terraces or as small areas within larger areas of outwash.

A thick outwash deposit of high permeability lies in the Tonawanda Creek valley south of Batavia. This outwash deposit contains open-work gravel which enhances its permeability. In addition its saturated thickness exceeds 70 feet. This is the most permeable large deposit known in the study basin.

The sand and gravel deposits that underlie lake deposits in the major valleys are not mapped. The location and thickness of these deposits are known only from subsurface data. The only such deposit developed for large ground-water supplies is at Gowanda. Small to moderate capacity public-supply wells are also developed from buried sand and gravel deposits at Holland, Varysburg, and at Hamburg for the Biehler Meadows development.

Hydraulic properties

Coefficients of transmissibility of the sand and gravel deposits given in table 4 were estimated on the basis of reported specific capacities of larger yield wells using graphs given by Walton (1962, p. 12-13). If the screened interval is small in relation to the thickness of the aquifer, the computed transmissibility applies mainly to the materials opposite the screen. The position of the aquifer and the depth of the screened interval are given to allow evaluation of these factors. The transmissibilities computed for some wells may be misleading because the drawdowns may have been affected by infiltration from streams. The transmissibility of the aquifer at well 259-809-1 is phenomenally high. Various wells drilled for the city of Batavia also had specific capacities that indicated similarly high transmissibilities. Yet, the transmissibilities computed from the specific capacities of wells 258-809-1 and 259-809-7 are an order of magnitude less. Irregularly distributed zones of open-work gravel in these deposits may account for this disparity.

Yields of wells

The yields of wells in the sand and gravel deposits vary greatly depending on the permeability and saturated thickness of the deposits and on well construction. Most wells for domestic supply are 6-inch diameter drilled wells with open-end casings. Such wells have low yields because they are necessarily inefficient; this type of construction is cheap and is adequate for household supplies. Wells drilled for public supplies are constructed for high efficiency and give a representative picture of the availability of water in the sand and gravel deposits. Efficient

Table 4.--Specific-capacity tests of wells finished in sand and gravel deposits

Well number	Pumping rate (gpm)	Drawdown (feet)	Specific capacity (gpm/ft)	Position of aquifer (feet below land surface) Top	Bottom	Screened interval (feet below land surface)	Coefficient of transmissibility (gpd/ft)
227-856-1	545	92	5.9	332	377	336-376	12,000
-4	517	81.3	6.4	301	347	303-333	12,000
229-822-1	425	30.5	13.9	1/ 24	75	64-74	17,000
229-856-1	150	9.5	15.8	1/ 19	35	30-35	18,000
230-840-1	830	25	33	100	157	119-138	40,000
231-825-1	150	3	50	1/ 16	48	38-48	55,000
-2	502	7.1	71	1/ 17	49	39-49	100,000
232-825-1	305	6.9	44.2	1/ 7	>53	44-49	60,000
234-856-3	254	19.3	13.1	1/ 11	>35	25-35	15,000
238-832-1	300	33	9.1	--	--	--	20,000
238-855-1	130	42.7	3.0	43	58	47-57	4,500
-2	137	12.6	10.9	1/ 9	24	19-24	13,000
239-853-1	115	42.4	2.7	47	54	49-54	3,500
246-836-1	690	46.5	14.8	40	>112	75-105	20,000
-2	700	102	6.9	72	>132	121-131	10,000
254-829-1	220	11.1	19.8	1/ 9	>34	29-34	25,000
258-809-1	456	12.8	35.6	1/ 26	>49	41-49	40,000
259-809-1	600	1.5	400	1/ 15	>64	40-60	600,000
-7	200	4.4	45.6	1/ 14	>60	50-60	60,000

1/ For a water-table aquifer, the depth to the water table is given.

wells yield 500 to 600 gpm from sand and gravel deposits in most valleys in the Uplands. The highly permeable outwash deposits in Tonawanda Creek valley provide yields of 1,000 to 1,400 gpm. Wells with these yields cannot be developed everywhere in the sand and gravel deposits. It is necessary to locate a sufficient thickness of water-saturated coarse-grained material (generally 10 to 20 feet), in which a screen can be set. Several test holes may be needed to locate the required aquifer materials. The success of communities and industries in developing large-yield supplies from sand and gravel deposits indicates that the relatively thick zones of permeable materials needed for well development are abundant.

ALLUVIUM AND SWAMP DEPOSITS

Some alluvium lies along all streams. Larger streams have built flood plains or terraces of alluvium consisting of silt, sand, and gravel. In most of the smaller streams with steep gradients, the alluvium is a bed deposit of gravel. The gravelly alluvium along Cattaraugus Creek is tapped for small supplies at places by means of driven and dug wells. Alluvial deposits otherwise are not significant sources of water.

Swamp deposits of muck and sediments lie in poorly drained areas. They generally mark areas of ground-water discharge. Because of their generally low permeability, they are not a significant source of water.

GROUND-WATER HYDROLOGY

The quantity of ground water in storage in the Erie-Niagara basin is enormous. Its magnitude can be roughly calculated as follows. Assume that the saturated zone available for development is 100 feet thick (it is certainly much thicker in many parts of the area) and that the porosity of the water-bearing formations is 10 percent (the porosity of much of the glacial deposits is higher but that of the bedrock is lower). These assumed figures indicate that storage in the ground-water reservoirs is equivalent to about 10 feet or 120 inches of water spread over the entire area, or about 2 billion gallons per square mile.

Ground water is added to storage intermittently as precipitation infiltrates the ground and percolates to the zone of saturation. This process is called recharge. It is obvious that if water were not also discharged from the ground, the ground would be water logged. Water moves through the saturated zone and discharges to the surface, generally to a stream, but in some places to springs or swamps. In its travels, a second type of ground-water discharge occurs. Plants whose roots extend to the saturated zone extract ground water from the ground and discharge it to the atmosphere as water vapor. Discharge equals recharge, except as relatively small changes in ground-water storage occur from year to year.

The estimate of 120 inches of ground water in storage is about 3 times the average annual precipitation and about 10 times the annual ground-water discharge. The replacement of water in storage obviously occurs at a slow rate. Despite this slowness, the ground-water reservoirs must be studied as dynamic systems. The usefulness of ground-water storage in providing supplies during periods of deficient precipitation is apparent. The reservoirs also function as conductors and transmit a considerable part of the water available for development from recharge areas to discharge areas. When ground water is pumped out of the ground, water moving through the reservoir is diverted toward the center of pumping. Natural discharge, and thereby streamflow, is ultimately reduced. Streamflow may also be reduced by a diversion of water from the stream into the ground as natural gradients are reversed due to pumping. Ideally, an understanding of the operation of ground-water reservoirs as part of a hydrologic system is needed in order to evaluate available ground-water supplies and the effects of their development on the total water regimen.

MOVEMENT OF GROUND WATER

How ground water moves from the point where it enters the saturated zone to the point where it is discharged is illustrated in figure 9. The most striking features of ground-water movement are the curvature of the lines of flow and the upward movement of the water as it approaches the discharge area. The upward flow of ground water may seem at variance with the behavior of water at the surface where water always flows downslope. Water at the surface flows downslope because it follows a

hydraulic gradient that results from gravity. Ground water likewise follows a hydraulic gradient, but the gradient results from head as well as gravity. The equipotential lines in figure 9 are lines of equal head. The ground-water gradient and, hence, the direction of ground-water flow, is at right angles to the equipotential lines. Theories of ground-water flow are set forth by Hubbert (1940) and Toth (1962a, 1962b).

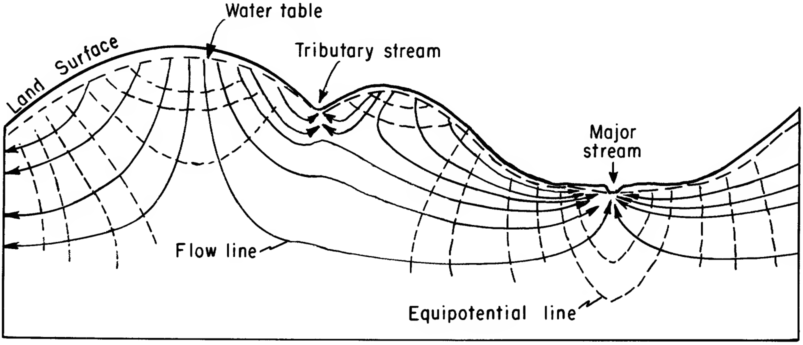


Figure 9.--Ground-water flow in a part of the Appalachian Upland section.

The paths of ground-water flow are generalized in figure 9. Ground-water flow concentrates in the more permeable zones in the unconsolidated deposits and follows the open fractures in bedrock. In detail, then, the paths of movement are irregular. Flow lines flatten out with depth because the permeability of the rocks decreases with depth and vertical circulation is restricted.

As can be seen from figure 9, minor flow systems can exist within a major system. Many small tributary streams draining hill slopes probably are fed by ground water discharging from minor flow systems. Figure 9 shows that only part of the water that infiltrates to the water table within the tributary drainage basin discharges within the basin. Water that infiltrates near the divide joins the major flow system and discharges to the main-stem stream. Furthermore, as the water table declines, its relief with respect to the tributary stream is considerably reduced and the amount of water moving through the minor flow system is substantially decreased. In the summer, as the water table falls, the amount of water moving through the minor flow system may be less than the evapotranspiration near the stream and the stream may dry up. The nature of the flow system explains why many tributary streams dry up in the summer even though the water table on the hill slopes remains at higher altitudes than the streambeds.

Differences in water levels among wells are also explained in the light of the flow system. Heads decrease with depth beneath recharge areas. Therefore, as a well in a recharge area is drilled deeper and deeper, its water level declines. Conversely, heads increase with depth beneath discharge areas and as a well is drilled deeper its water level rises.

CHANGES IN STORAGE

The ground-water reservoirs of the Erie-Niagara basin undergo seasonal changes in storage that are typical of the northeastern United States. A change in storage is brought about when recharge and discharge occur at different rates. Storage is almost always changing because recharge and discharge are equal only as a transient condition. The pattern of storage fluctuations is shown by the hydrographs in figure 10. The hydrographs are plots of water levels in selected wells that are unaffected by pumpage and, therefore, indicate, in a qualitative sense, fluctuations in storage.

What brings about the seasonal fluctuations in ground-water storage? Ground-water discharge is a continuing process. Its rate varies with the volume of water in storage because the higher the water levels in the ground, the steeper is the gradient to the streams and hence the higher is the discharge. The rate of decline of water levels in wells decreases as the levels drop. This fact is reflected in the hydrographs (fig. 10). Recharge is intermittent because it can occur only as a result of rain or snowmelt. Because precipitation is rather uniformly distributed throughout the year, there is year-round potential for recharge. The hydrographs show, nevertheless, that recharge is negligible from late spring to early fall. A third variable, evapotranspiration, fluctuates seasonally and is responsible for the observed seasonal lack of recharge.

The potential evapotranspiration shown in figure 11 is computed by the method of Thornthwaite and Mather (1957). During the growing season, evapotranspiration exceeds precipitation. Soil water is needed to supplement the demand made by plants so that a deficiency of soil moisture generally develops. During the middle part of the growing season, most of the precipitation that infiltrates is held in the soil. Only during an exceptionally wet period during the summer will the field capacity of the soil be exceeded so that infiltration can reach the water table.

Several characteristics of the ground-water regime are indicated by the water-level hydrographs (fig. 10):

(1) The zone of aeration acts as a reservoir and, where either thick or in fine-grained material, yields water slowly to the saturated zone. This dampening of increments of recharge is shown by the hydrograph of well 238-844-4, which penetrates a sand and gravel deposit containing water under water-table conditions. Infiltration into the soil occurs in discrete increments, yet the water level in the well rose gradually through periods of several days to 1 1/2 months.

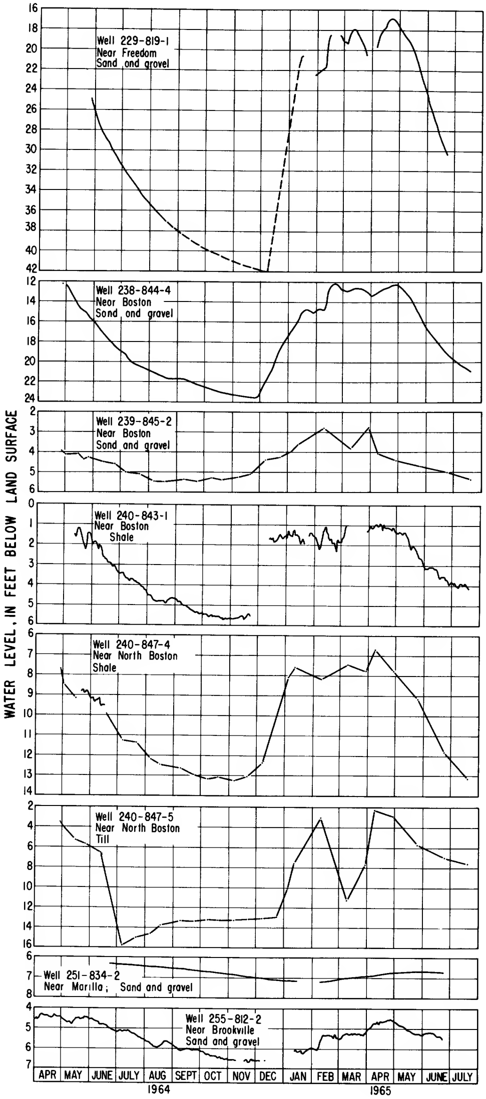


Figure 10.--Water levels in observation wells. A continuous record is shown by a solid line. A record obtained by periodic measurements is indicated by a dot for the measurement and intervening straight lines. Estimated water levels are shown by dashed lines.

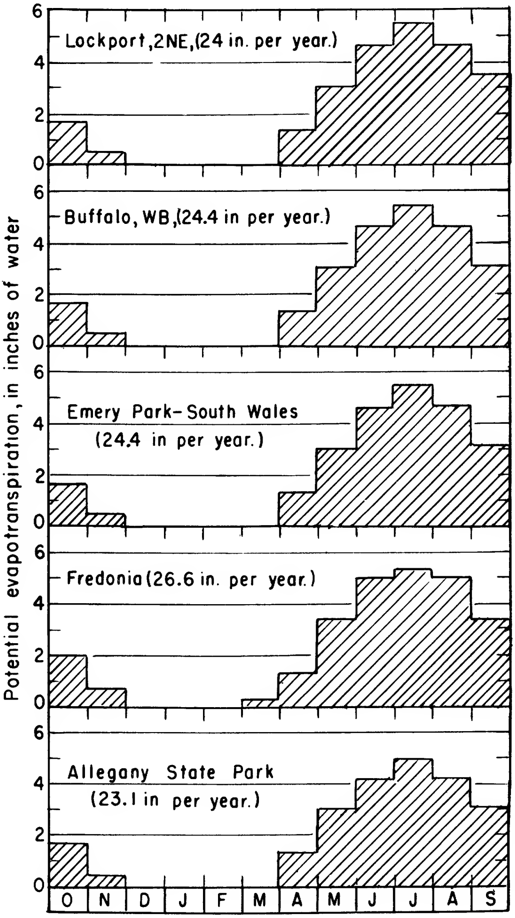


Figure 11.--Normal monthly potential evapotranspiration at climatological stations in and near the Erie-Niagara basin.

(2) Changes in storage are brought about by the percolation of streamflow into the ground as well as by the discharge of ground water to streams. The sand and gravel deposits near Freedom penetrated by well 229-819-1 (fig. 10) are recharged

by tributaries of Cattaraugus Creek. The headwaters of the stream near the well are perennial, but in the summer the streamflow percolates into the ground upstream from Freedom. At base flow a steady recharge is received from the stream, but this is considerably exceeded by discharge from the aquifer through subsurface flow down the valley. The hydrograph for the well is discontinuous, but it is apparent that sharp increments of recharge were received by the aquifer in January, February, and March of 1965. These rapid rises in level are at variance with those of well 238-844-4, discussed previously, and probably were caused by recharge from the stream when it flowed at high stages.

(3) Till and bedrock form a two-aquifer system. The geology and hydrology of the area require that the bedrock be recharged mainly by downward percolation from till on hilltops. Water-level fluctuations in the two units can be expected to be of different magnitudes because of differences in water-bearing properties. Where the recharge area of the bedrock is remote, the fluctuations in the two units may also be somewhat out of phase, as is shown by the hydrographs for wells 240-847-4 and -5.

(4) Wells in water-table aquifers close to streams show a narrow range of fluctuation. From April 27, 1964, to July 19, 1965, the water level in well 239-845-2 (measured bimonthly) fluctuated through a range of only 2.7 feet. Near streams, water-table aquifers receive water traveling along flow paths from recharge areas, but they also discharge water to the stream. The net effect is that there is little change in ground-water storage in the aquifers near streams. The water-level fluctuation at the well is due to the rise and fall of the stream stage, to recharge by direct infiltration, and to discharge by evapotranspiration in the immediate vicinity of the well.

(5) Wells in deposits that are remote from the recharge area have gradual fluctuations in water level that are usually out of phase with the trend of water levels in wells closer to areas of recharge. The hydrograph of well 251-834-2 is smooth, and the trend of the water level in the well lags the seasonal trends shown by other observation wells. This lag represents the time required for water to move from the recharge area to the well. The water-level fluctuations in the well are of a small magnitude because ground water from the deposits is discharging to a small stream 600 feet to the northwest.

(6) Confined aquifers undergo the same pattern of seasonal storage changes as water-table aquifers. However, water levels in wells in confined aquifers have many minor fluctuations of short duration that are superimposed on the seasonal ones, as is shown by the hydrographs of wells 240-843-1 and 255-812-2. The small, irregular pressure changes apparent on the

hydrographs are probably due to changes in atmospheric pressure. An increase in atmospheric pressure drives the water level down in a well tapping a confined aquifer. The water level in the well recovers as the atmospheric pressure decreases. The physical explanation of this phenomenon is given by Ferris and others (1962, p. 83-85). Thus, minor fluctuations of a diurnal (daily) nature observed in such wells are not indications of changes in storage, as are the longer term fluctuations.

GROUND-WATER DISCHARGE

The flow of water through the saturated zone is described by Darcy's Law:

$$Q = TIL$$

where: Q is discharge in gallons per day,

T is transmissibility in gallons per day per foot,

I is the hydraulic gradient in feet per foot,

L is the width, in feet, of the cross section through which discharge occurs.

This law can be applied to the Erie-Niagara basin in the general fashion shown in figure 12. If d (the distance from the stream) is constant, h (the height of the water table above the stream) is directly proportional to Q (the ground-water discharge to the stream). The depth to the water level in a well at a distance, d, is complementary to h, and therefore is inversely proportional to Q. Darcy's Law, therefore, suggests that a relationship can be developed between ground-water levels in wells and that portion of streamflow derived from ground-water discharge.

In periods of sustained dry weather, streams are supplied only by ground-water discharge. At other times, the stream is supplied also by overland runoff. On a hydrograph of a stream-gaging station, the periods of base flow (essentially ground-water discharge) are characterized by gentle recessions in flow. The periods of overland runoff are characterized by sharp increases in flow followed by steep recessions.

The relationship between ground-water levels and streamflow can be determined by plotting ground-water levels against average daily streamflow for periods when base flow was occurring. A typical plot is shown in figure 13. A curve can be drawn through the points. Points falling to the right of the curve do so because the stream was not truly at base flow on the days chosen. The graph is a curved line because the saturated thickness of deposits contributing ground water to the stream shrinks as ground-water storage is depleted.

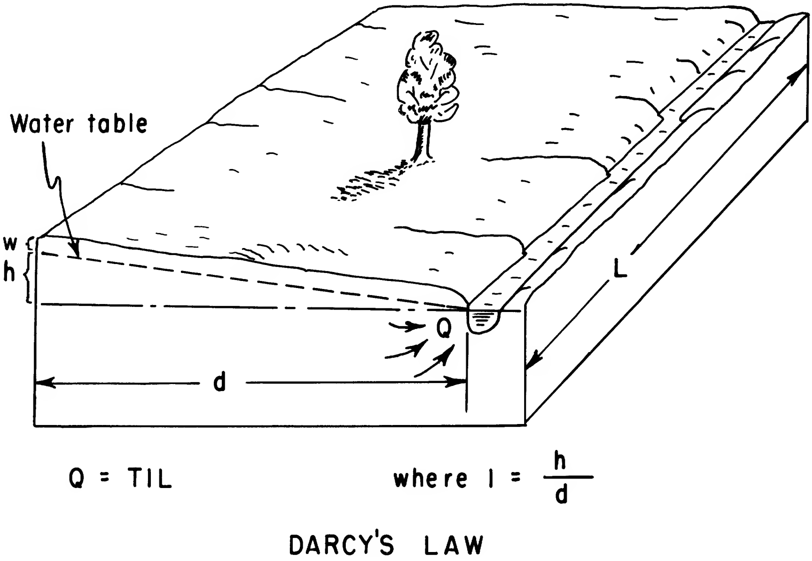


Figure 12.--Application of Darcy's Law to ground water discharging to a stream.

This type of graph, or ground-water rating curve, allows ground-water discharge to be estimated for those periods when overland runoff occurs. Figure 14 shows a hydrograph of ground-water discharge plotted on the basis of ground-water levels and rating curves for wells in the Eighteenmile Creek valley.

To assess the quantity of ground-water discharge, hydrographs of ground-water discharge were also drawn for the gaging stations on Little Tonawanda Creek at Linden, Buttermilk Creek near Springville, and Cattaraugus Creek at Arcade on the basis of ground-water levels in those basins. These hydrographs are given by Archer and others (1968). Ground-water discharge hydrographs for Buffalo Creek at Gardenville, Buffalo Creek near Wales Hollow, and Cattaraugus Creek at Gowanda (Archer and others, 1968), were drawn by the base-flow recession method (American Society of Civil Engineers, 1949, p. 71-73) and by comparison with the hydrographs prepared from ground-water rating curves.

Approximate ground-water discharge hydrographs could be drawn partly by inspection and partly by the base-flow recession method. Without information on ground-water levels, however, the separation of the ground-water component of flow from the high stream discharges would be dubious.

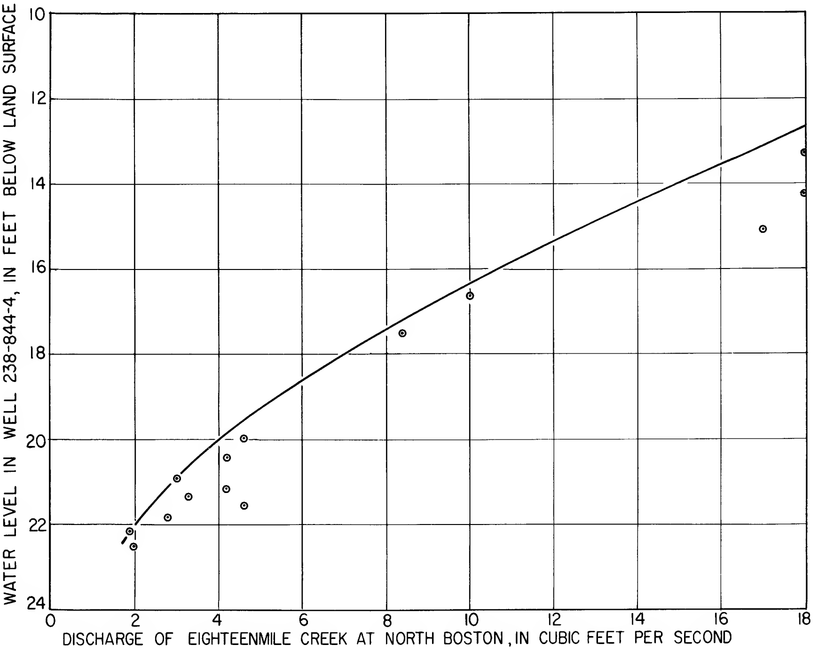


Figure 13.--Rating curve of ground-water discharge to Eighteenmile Creek.

To evaluate the long-term aspects of ground-water discharge, duration curves of ground-water discharge were drawn by a method developed by Wilbur T. Stuart (U.S. Geological Survey, written communication) and are given in figure 15. Additional duration curves for the area are given by Archer and others (1968). Streamflow-duration curves adjusted to a base period of 1931-60 are available for all gaging stations in the area. In Stuart's method, the ground-water duration curve and the streamflow-duration curve are considered to be coincident to the right of the 90-percent duration point. In other words, the lowest flows recorded are assumed to be entirely ground-water discharge. The left-hand intercept of the ground-water duration curve is the maximum ground-water discharge. The value of this maximum was estimated by (1) extending the base-flow recession curves upward beneath the periods of very high streamflow, and (2) Darcy's Law, using the estimated transmissibility of the aquifers in each basin and the ground-water gradients. The ground-water duration curve was drawn between the left-hand intercept and the 90-percent point of the streamflow-duration curve by the following procedure. A smooth curve was drawn asymptotic to

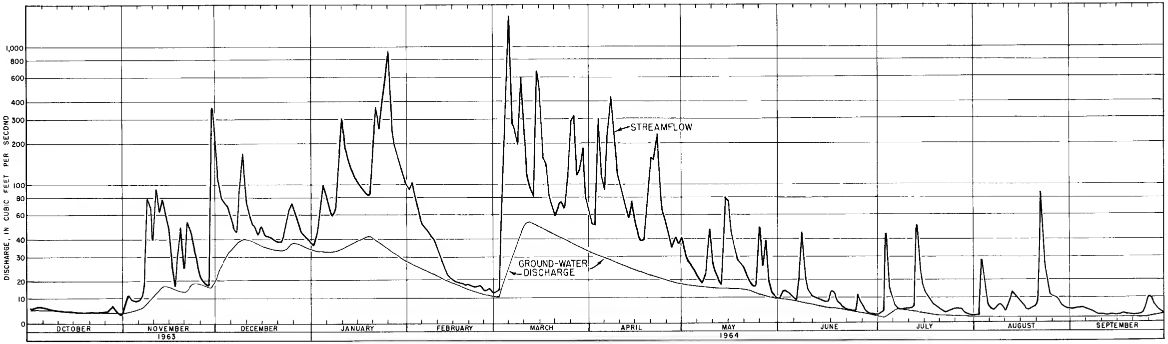


Figure 14.--Ground-water discharge and streamflow, Eighteenmile Creek at North Boston.

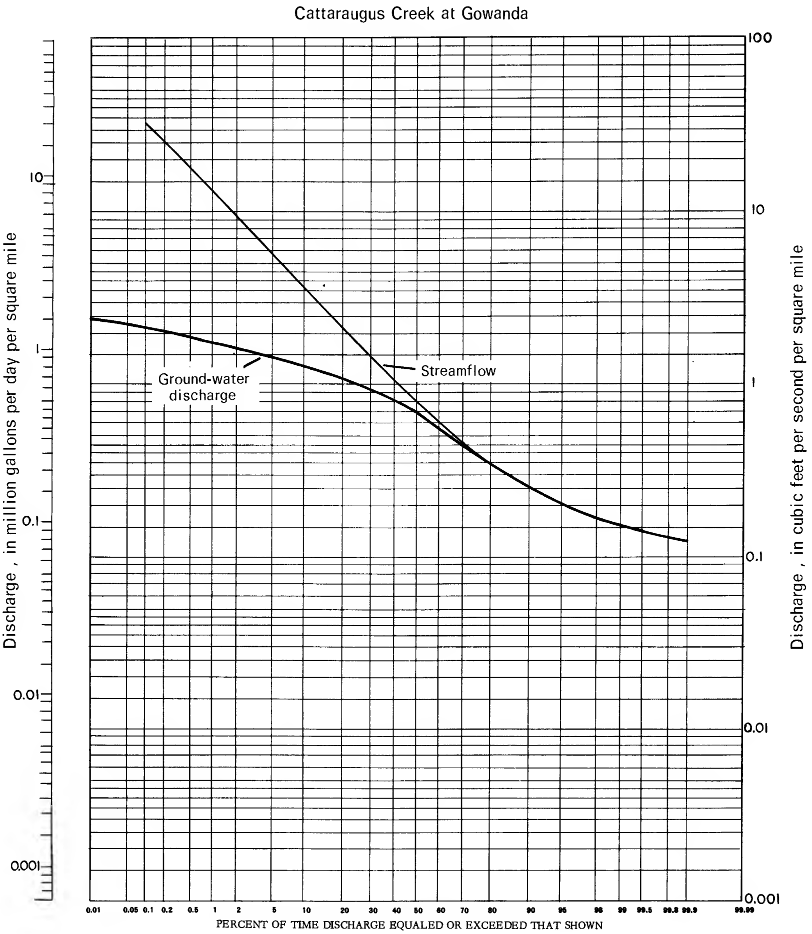


Figure 15.--Duration curves of ground-water discharge and streamflow.

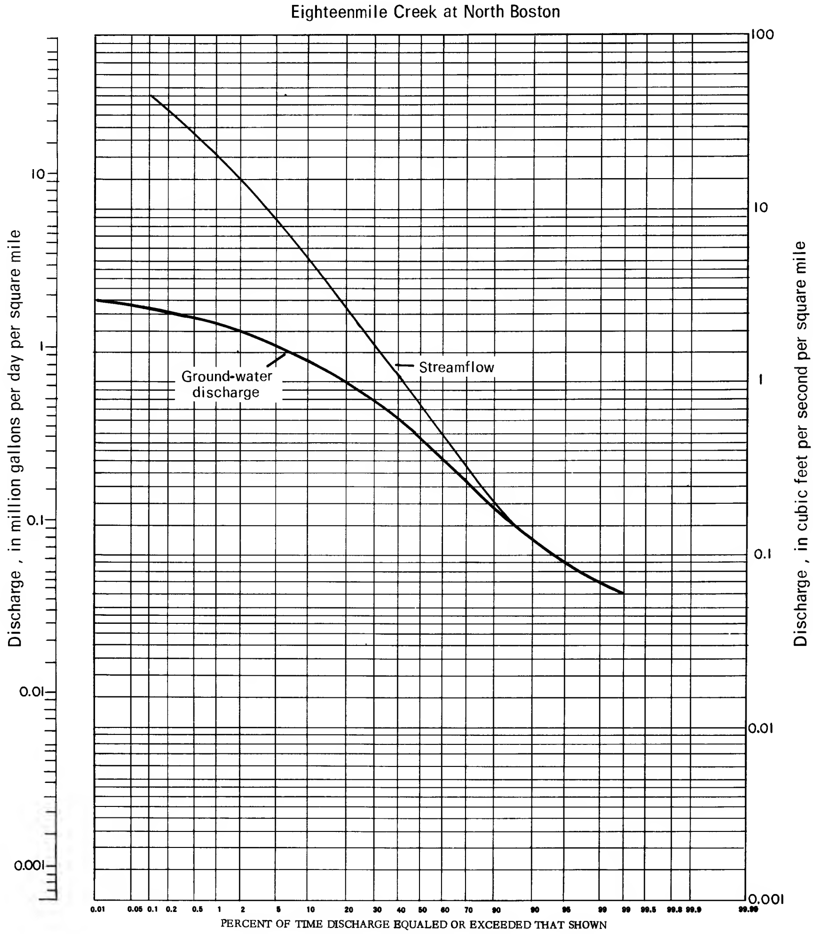


Figure 15.--Duration curves of ground-water discharge and streamflow (Continued).

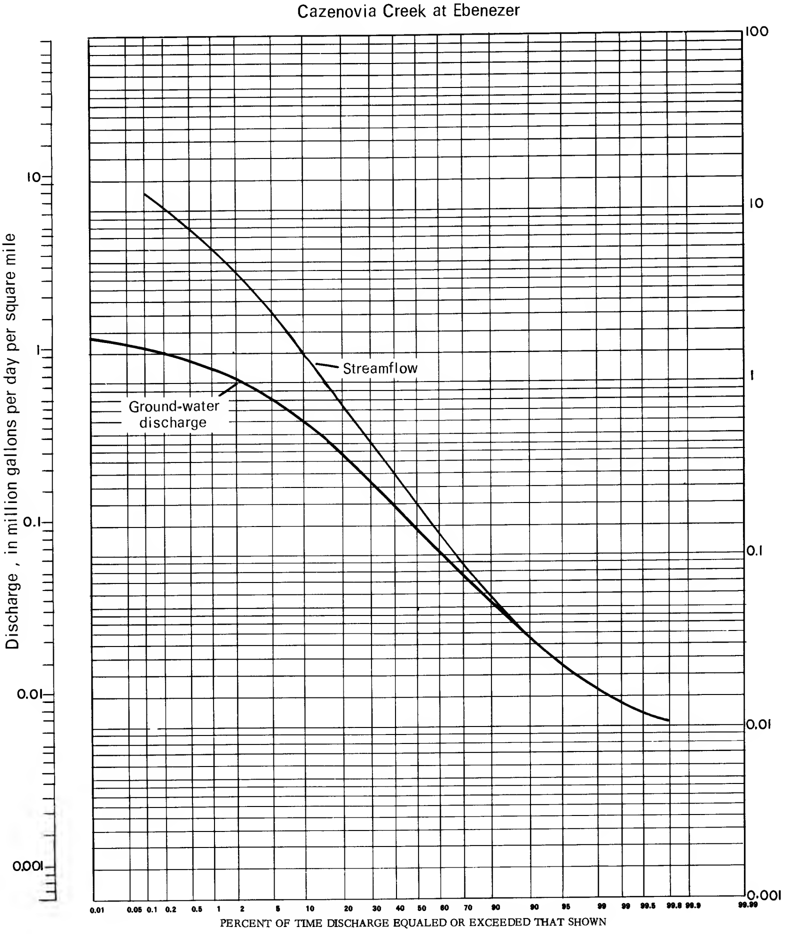


Figure 15.--Duration curves of ground-water discharge and streamflow (Continued).

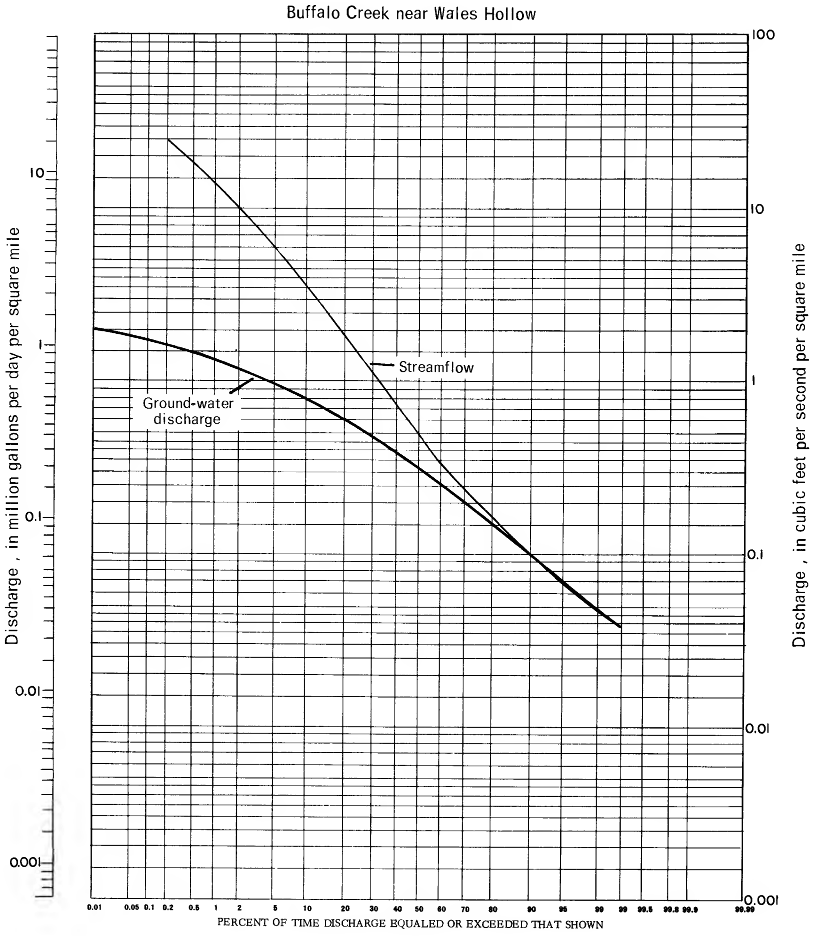


Figure 15.--Duration curves of ground-water discharge and streamflow (Continued).

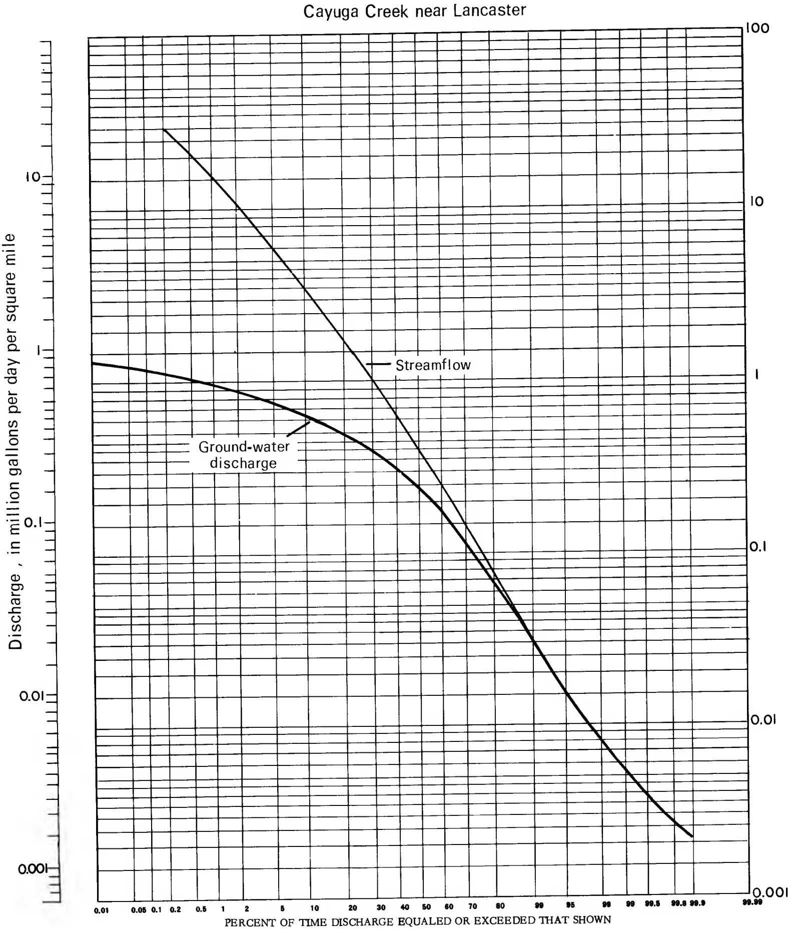


Figure 15.--Duration curves of ground-water discharge and streamflow (Continued).

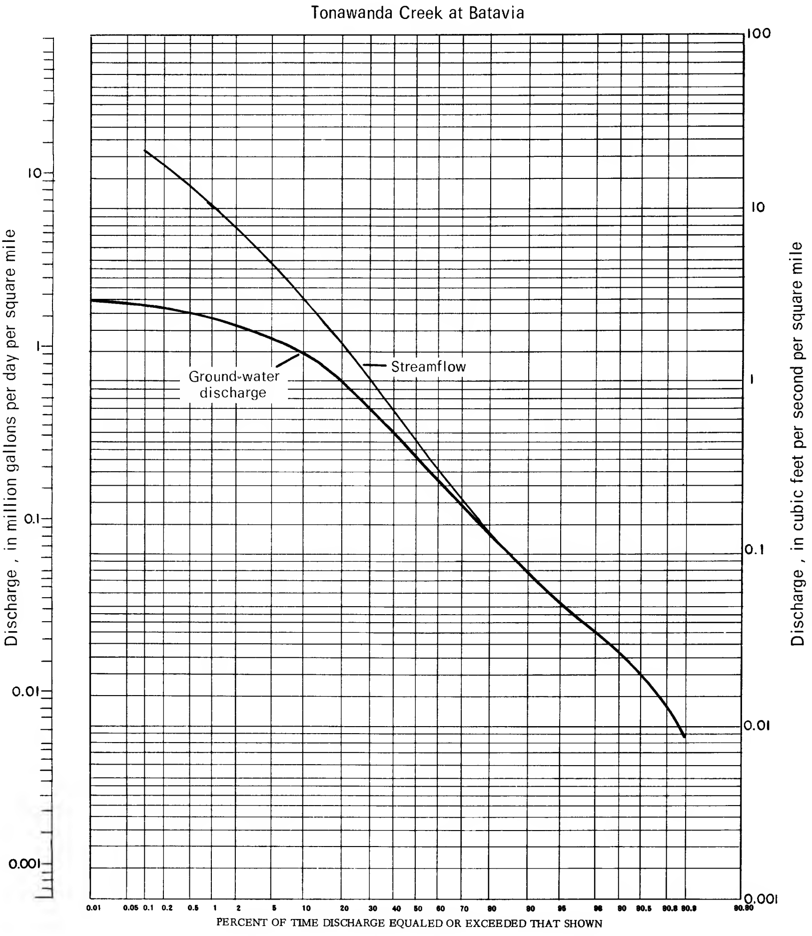


Figure 15.--Duration curves of ground-water discharge and streamflow (Continued).

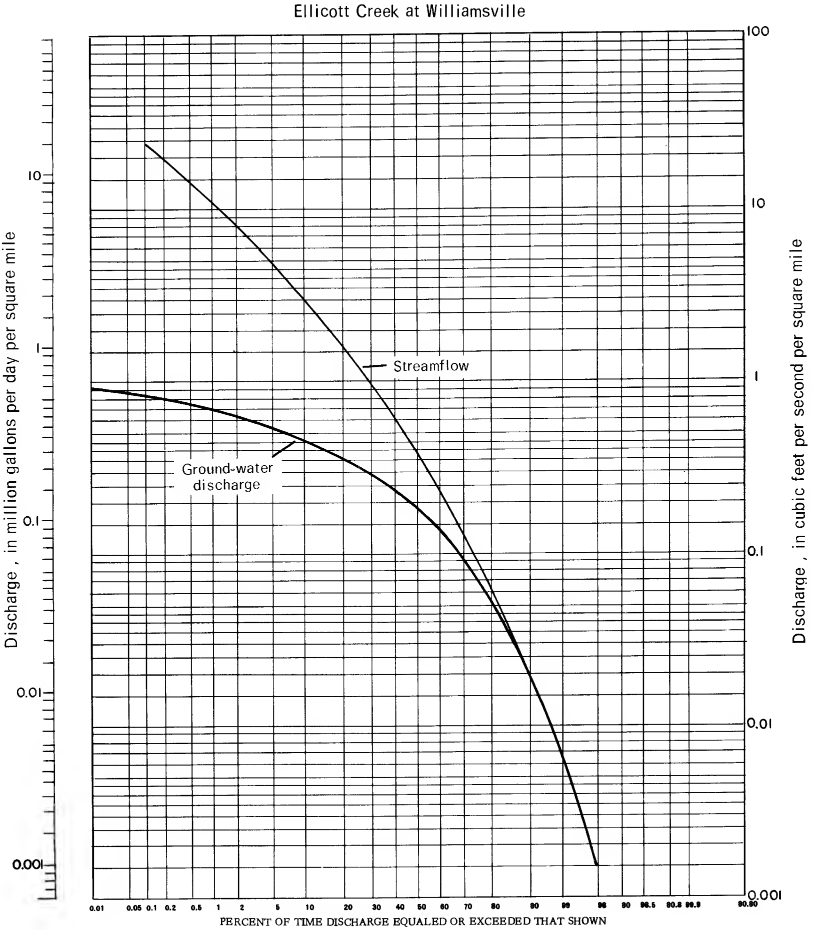


Figure 15.--Duration curves of ground-water discharge and streamflow (Continued).

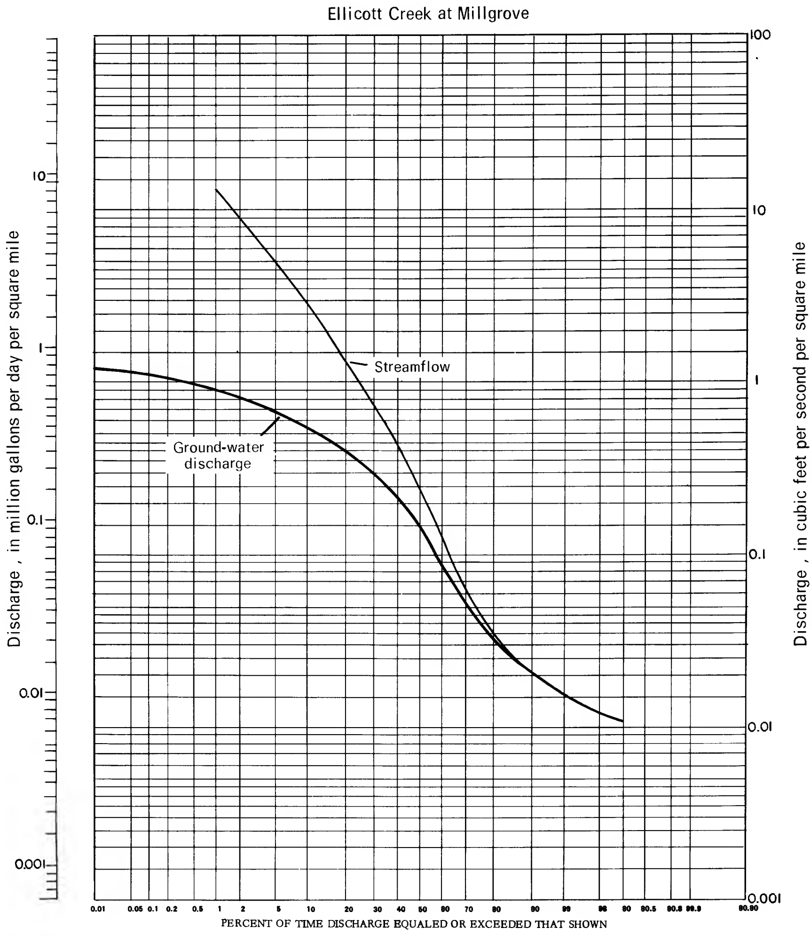


Figure 15.--Duration curves of ground-water discharge and streamflow (Continued).

both the streamflow-duration curve at its upper end and the lower part of the 90-percent duration line. This smooth curve represents a duration curve of overland runoff and its shape is based on flow-duration curves for streams draining basins with little ground-water discharge. The differences in values between both curves for corresponding duration points were then plotted. The computed points represent ground-water discharge (the difference between streamflow and overland runoff). The shape of the overland runoff duration curve was adjusted if necessary so that the computed points formed a smooth curve which represents a ground-water duration curve. Obviously, the ground-water duration curves are approximations, but each was prepared by the same method and, therefore, provide a means of comparing ground-water discharge from different valleys in the area.

The ground-water duration curves reflect differences in ground-water discharge arising principally from variations in the lithology and thickness of aquifers.

Ground-water discharge from thick and extensive sand and gravel deposits is not only large but also enduring, so that streamflow is sustained at relatively high rates through the summer during periods of little or no precipitation. The effect of ground-water discharge from sand and gravel deposits on the streamflow regimen of Cattaraugus Creek basin is shown in figure 15 of this report and in Archer and others (1968). The Cattaraugus Creek basin receives ground-water discharge at a higher rate than any other basin in the area on the basis of both total discharge and discharge per square mile of drainage basin. The ground-water discharge to Cattaraugus Creek falls off slowly during the summer as shown in the hydrograph for the 1964 water year (Archer and others, 1968). The slow decline of ground-water discharge during the summer is also reflected in the flat slope of the right part of the ground-water duration curves for the stream. The ground-water duration curves shown by Archer and others (1968) for other streams, all of which flow north or northeast, indicate lower rates of ground-water discharge. The lowland areas of these streams are basins containing stratified glacial deposits and are narrow compared to those of the Cattaraugus basins. A large proportion of the glacial deposits in the northward-trending valleys are fine grained because they were deposited in glacial lakes. The deposits are, therefore, low in permeability. Cayuga Creek and Ellicott Creek basins, because they lack a significant amount of sand and gravel deposits, receive a relatively small amount of ground-water discharge, particularly at the higher duration points (fig. 15). The table in plate 4 summarizes the amount of ground water discharged to streams in the area.

Duration curves of ground-water discharge not only indicate differences in the ground-water regimen of the area, but make it possible to appraise the effect of large ground-water withdrawals on streamflow. These effects may show up as (1) a reduction in natural discharge from the aquifer to the stream, (2) a reduction in streamflow by induced infiltration from the stream to the aquifer, and (3) a reduction in streamflow during periods of high flow as ground-water storage in the pumped area is replenished. A hydraulic analysis of the diversion of water from a stream to a pumped well can be made from a method developed by Theis and Conover (in Bentall, 1963b, p. C106-109).

GROUND-WATER RECHARGE

The data on ground-water discharge apply to the water moving past the stream-gaging stations and represent discharge from large expanses of aquifers upstream from the gages. The data do not reveal where the water entered the ground, the paths it traveled, and the reaches of the channel where it left the ground. The problem is to estimate the quantity of ground water with respect to where it can be obtained.

Most of the land surface of the Erie-Niagara basin is directly underlain by unconsolidated deposits. The hills in the Appalachian Uplands are underlain by till; the valley bottoms and terraces near the streams are underlain by stratified glacial deposits consisting of silt and clay deposits and sand and gravel deposits. The Erie-Ontario Lowlands are underlain mainly by till and silt and clay deposits, though some sand and gravel deposits occur near streams. The sand and gravel deposits, being permeable and giving rise to permeable soils, will accept infiltration from precipitation at a high rate. Till, clay, and silt, because of their low permeabilities, accept infiltration at a slow rate. Therefore, the aquifers that receive the greatest amount of recharge are the sand and gravel deposits which are thickest and most extensive in the valleys of the Appalachian Uplands.

Consider a light rain falling at a slower rate than the soils in the area will admit water. All of the rain infiltrates the ground (direct infiltration). The rain increases in intensity, so that it is falling faster than the rate at which water can infiltrate the less permeable soils. All of the rain falling on the more permeable soils is still infiltrating, but part of the rain falling on the less permeable soils, such as overlie till, is shed downslope as sheet flow and flows in rivulets and streams. Now a second type of ground-water recharge occurs. Some of the water flowing off the hills reaches the sand and gravel deposits in the valleys and infiltrates them by percolating through the soil or the beds of rivulets that lie above the water table. If the runoff from the hill slopes flows in a stream that is incised to the water table in the sand and gravel deposits, then no recharge will occur along the stream. An appreciable rise in the stage of such a stream will cause water to move into the deposits near the banks. This so-called bank storage will return to the stream rather rapidly once the stream stage declines. A mathematical treatment of the flow of water into and out of bank storage has been developed by Cooper and Rorabaugh (1963).

It is important to know the rate of recharge to the sand and gravel because these deposits represent sources for development of large supplies of good quality water. Recharge to the deposits along with induced stream infiltration sets the upper limit of pumpage from them. Plate 4 is a map that shows the average annual recharge to the sand and gravel deposits. In preparing the map it was assumed that water infiltrating within the flow system directed toward sand and gravel deposits eventually becomes available from them. The following factors were used:

(1) Where precipitation is about 40 inches per year, direct infiltration on the surface of sand and gravel deposits averages 500,000 gpd per square mile and ranges from 300,000 to 600,000 gpd per square mile; where precipitation is about 30 inches per year, direct infiltration averages about 300,000 gpd per square mile and ranges from 150,000 to 400,000 gpd per square mile.

(2) The part of the direct infiltration on till which eventually reaches the sand and gravel deposits is about 50,000 gpd per square mile.

(3) Peripheral recharge to the sand and gravel deposits by runoff from till and bedrock is 300,000 to 500,000 gpd per square mile of contributing area depending on the annual precipitation.

To check these figures, which are based partly on unpublished data from the Albany, New York, area and are partly estimates, ground-water discharge indicated by hydrographs and duration curves at several gaging stations was compared to ground-water discharge computed on the basis of the figures and the area of the various deposits. Most results agreed within about 20 percent.

Observation-well data can be used to further check the computations that were made from the theoretical recharge values. For instance, the water-level fluctuations at well 229-819-1 at Freedom (fig. 10) indicate the change in ground-water storage attributable to recharge received by the sand and gravel deposits there during the 1965 water year. The water level in the well rose about 21.5 feet from an estimated depth of 42 feet in December 1964 to April 1965; an estimated 5 feet during the period from January 29 to February 25, 1965; 1.5 feet from March 3 to March 10, 1965; and an estimated 4 feet during the period March 25 to April 21, 1965. These rises total about 32 feet. If a specific yield of 0.20 (an average figure for sand and gravel) is assumed, the increase in ground-water storage during this period was about 77 inches of water or 3.7 mgd per square mile. The recharge to the deposit was actually greater because the recharge during the period also was replacing water discharging from the deposits as well as increasing the ground-water storage. The average annual recharge to the deposits at Freedom was computed as 4.1 mgd per square mile on the basis of the theoretical values. This computation checks reasonably well with the computations based on water-level fluctuations in well 219-819-1.

Recharge of the ground-water reservoirs occurs mainly in the spring and is not evenly distributed through the year. The water that enters ground-water storage does not remain perennially available but discharges to the streams. The rate of discharge is not constant and declines as the amount of water in storage decreases. For example, for Cattaraugus Creek at Gowanda, the ground-water discharge at the 50-percent duration point is 190 mgd but is only 71 mgd at the 90-percent duration point. Ground-water discharge to streams in the Erie-Niagara basin at the 50-, 90-, and 99-percent duration points are given in the table in plate 4. The average

ground-water discharges shown in the table approximates the ground-water replenishment shown on the map in plate 4. The duration information indicates the variation in the availability of ground water under natural conditions. When pumpage is large and ground-water levels are significantly lowered, the ground-water regime is changed and less ground water is lost through natural discharge, as will be explained later in the section on "Methods of increasing recharge and controlling storage."

INDUCED INFILTRATION

In addition to recharge produced by direct infiltration of precipitation and infiltration of overland runoff as shown in plate 4, recharge can also be induced from streams by pumping wells. When a well in a permeable deposit near a stream is pumped at a high rate, the cone of depression around the well intersects or passes under the stream. A hydraulic gradient is created from the stream toward the well, and the aquifer is recharged by the stream water. The effectiveness of the stream infiltration is dependent on the distance of the well from the stream and the permeability of the streambed.

Induced infiltration probably occurs in the vicinity of the public-supply wells of North Collins, East Aurora, and Arcade. The potential is large for increasing ground-water recharge by induced infiltration whereever perennial streams cross sand and gravel deposits. The amount of water that can be induced to infiltrate is probably equivalent to the streamflow at about the 70- to 90- percent duration (fig. 15).

Where the Camillus Shale and the limestone unit lie near streams or Lake Erie, induced infiltration can add measurably to the quantity of water available. The inducing of infiltration from the Niagara River to the Camillus Shale by wells at the E. I. du Pont de Nemours & Co. plant in Buffalo is indicated by the temperature graphs in figure 16. At the time of the temperature measurements, pumpage from a north well field (which includes well 257-855-1) was 200,000 gpd and pumpage from a south well field (which includes well 257-855-2) was 1 mgd. Distance between the well fields is about 1,000 feet. The north well field is about 900 feet from the Niagara River and the south well field is about 800 feet from the river. Temperature of ground water in the Camillus Shale is about 50°F with an annual temperature range of about 1 or 2°F. However, the temperature range of water pumped from the north well field is about 12°F. The temperature range of the Niagara River shown in figure 16 was about 41°F. Cold water from the river infiltrating the Camillus during the winter lowered the ground-water temperature and warm water infiltrating in the summer raised the ground-water temperature. Thus, the water pumped from the south well field had a much greater temperature range than is normal for ground water in the Camillus. As can be seen in figure 16, the temperature fluctuation in the south well field was out of phase with the river temperature by about 3 months. This represents the approximate travel time of water from the river to the well field.

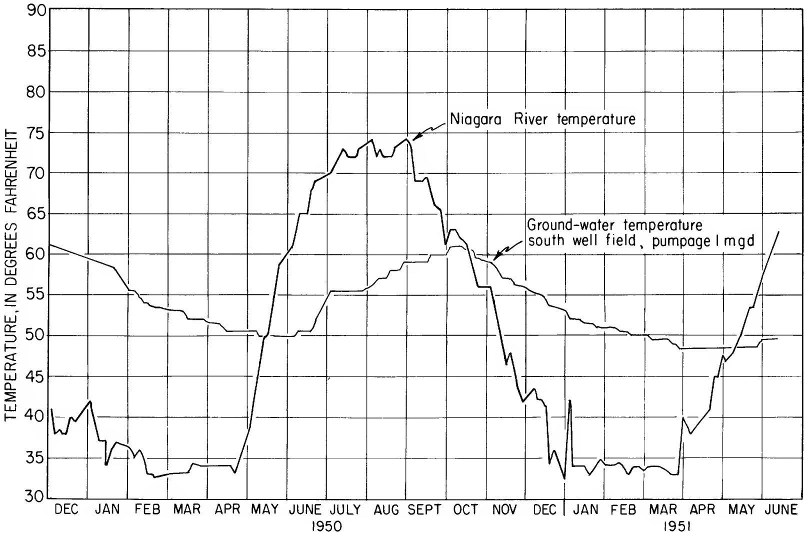


Figure 16.--Comparison of the temperature of ground water from wells and of the Niagara River to demonstrate induced infiltration.

CHEMICAL QUALITY OF GROUND WATER

The chemical quality of ground water greatly affects its use. In general, the higher the dissolved-solids content of the ground water, the fewer are the uses for which it is suitable without treatment. Some uses, such as public water supply, require water with a relatively low dissolved-solids content, whereas other uses, such as industrial cooling, can be met with water of high dissolved-solids content. Individual characteristics of the water or the excessive concentrations of a particular constituent may be a detriment, even though the dissolved solids are relatively low in concentration. For instance, ground water with an iron concentration of greater than 0.3 ppm may exhibit a brown precipitate of iron when exposed to the air. The tendency of this iron precipitate to cause staining of the housewife's wash will inhibit the use of the ground water. The significance of the dissolved constituents and the properties of water in the Erie-Niagara basin, from the standpoint of use, are given by Archer and others (1968). Water can be treated to reduce some excessive constituents such as hardness and iron. The concentrations of other constituents, such as chloride and sulfate, cannot be economically reduced in the Erie-Niagara basin.

Ground water with the lowest concentrations of dissolved solids in the basin occurs in the surficial sand and gravel deposits in the Appalachian Uplands, in which dissolved solids range from about 175 to 300 ppm (parts per million). The poorest quality ground water occurs in the outcrop belt of the Camillus Shale in the northern part of the basin, in which dissolved solids range from about 800 to 5,000 ppm. Plate 5 summarizes the data on concentrations and distribution of common chemical characteristics of ground water in the bedrock within depths commonly reached by water wells. The chemical quality of ground water in the unconsolidated deposits is not as easily portrayed on maps because of its variability, particularly with depth. In general, ground water at shallow depth in the unconsolidated deposits is lower in dissolved solids than water in the underlying bedrock. Archer and others (1968) present a map showing the quality of water in streams during base flow. Archer's data are representative of the average quality of shallow ground water and of the quality of ground water that will generally be obtained by large-scale development.

SOURCES OF DISSOLVED SOLIDS

The chemical constituents in ground water are obtained mainly from the solution of rock materials, both from the zone of aeration as water percolates down to the water table, and from the zone of saturation as the water moves toward areas of discharge.

The rocks of the basin contain four relatively soluble minerals: Calcite ($CaCO_3$), the major constituent of limestone; dolomite ($Ca\,Mg(CO_3)_2$); gypsum ($CaSO_4 \cdot 2H_2O$); and halite, or common salt ($NaCl$). Calcite and dolomite are distributed throughout the area, not only in the carbonate

rock units shown in figure 2, but in the glacial deposits, which contain an abundance of fragments eroded from the carbonate rocks. Also, most of the shale units are calcareous. All ground water in the area then is certain to come into contact with carbonate minerals. Gypsum is abundant only in the Camillus Shale but is present in minor amounts in the Lockport Dolomite. Salt occurs only at depth in the Camillus Shale. The boundary of the salt in the Camillus, as given by Kreidler (1957, pl. 1), is shown on the chloride content map in plate 5.

The minerals that form the bulk of the rocks in the area are siliceous and have low solubilities. Various clay minerals (complex hydrated silicates) and quartz (silica) make up the bulk of the shale units and also occur in the limestone units. Chert, a form of silica, is abundant in the limestone.

The analyses in tables 8 and 9 clearly demonstrate that the chemical characteristics of the water in the area are due mainly to the solution of calcite, dolomite, gypsum, and salt, because calcium, magnesium, sodium, bicarbonate, sulfate, and chloride are present in the water in significant concentrations. The siliceous minerals contribute relatively little material to ground water as is shown by the low concentrations of silica, because silicate minerals are relatively insoluble in water.

WATER REACHING THE WATER TABLE

The water that infiltrates the ground, either directly or after flowing on the land surface as overland runoff, is generally low in dissolved solids. Data given by Archer and others (1968) show that precipitation in the Erie-Niagara basin generally contains 15 to 50 ppm of dissolved solids and overland runoff generally contains 50 to 100 ppm of dissolved solids. Water from a few rainfalls contains as much as 200 ppm of dissolved solids and from a few snowfalls as much as 400 ppm. The overland runoff resulting from such storms would be correspondingly high in dissolved solids.

When water infiltrates through the land surface, its content of dissolved solids begins to increase. Water will dissolve gypsum, salt, and even the much less soluble siliceous minerals on contact. The solution of calcite and dolomite, however, largely depends on the presence of dissolved carbon dioxide (or carbonic acid) in the water. Atmospheric water contains sufficient carbon dioxide to dissolve 20 to 30 ppm of calcium (Hem, 1959, p. 74) and 60 ppm of bicarbonate (the product of the dissociation of the carbonate minerals); that is, if other constituents in the water do not interfere with the chemical reaction. When water percolates into the soil it enters a zone of abundant carbon dioxide. Plant roots give off carbon dioxide at a high rate and soil air may contain 1 to 5 percent of carbon dioxide (Hem, 1959, p. 76). Water that has percolated through the soil zone is capable of dissolving 70 to 110 ppm of calcium (Hem, 1959, p. 76) and 210 to 330 ppm of bicarbonate. However, water probably does not become saturated with respect to calcite or dolomite in the zone of aeration and may flow a considerable distance in the zone of saturation before saturation is achieved.

The chemical quality of water reaching the water table and of ground water of local origin at shallow depth in the southern part of the area probably is indicated by the analyses of samples from wells 226-838-5 and 227-838-2 (table 8). Both these wells are cased with steel pipe and sealed at the land surface, so that water may enter them only from the saturated zone after percolating through the zone of aeration. A comparison of the samples for these wells with that for well 226-839-3 (table 9) indicates the effect on water quality of the zone of aeration. Well 226-839-3 exhibits a feature peculiar to large-diameter wells that are lined with a fieldstone cribbing. Water that flows over the land surface can enter wells of this construction through loosely compacted materials around the cribbing and flow into the well within a short vertical distance through the openings between the fieldstones. The water has little contact then with the zone of aeration. Well 226-839-3 is in a site where surface drainage is directed toward it. A continuous water-level record for the well indicates that sudden and large rises in water level were caused by surface runoff entering the well. The water seeped from the well into the surrounding till at an extremely low rate, so that when the well was sampled in May 1963, the water quality was mainly that of overland runoff. Archer and others (1968) give analyses of overland runoff that approximate the analysis for the sample from this well, which has a hardness of 42 ppm and dissolved solids of about 70 ppm (computed from a specific conductance of 116 micromhos). The samples from wells 226-838-5 and 227-838-2, on the other hand, have a hardness of 137 ppm and dissolved solids of 159 and 154 ppm, respectively. Passage through the zone of aeration and a small part of the zone of saturation by the water sampled in the latter two wells apparently increased both the hardness and the dissolved solids by about 90 ppm mainly by solution of carbonate rock fragments contained in the glacial deposits.

In the northern part of the basin, ground water at shallow depth in the unconsolidated deposits has a comparatively high sulfate concentration, particularly where the unconsolidated deposits overlie the Camillus Shale as shown by analyses of samples from wells 305-845-1 and 306-827-1 (table 9). This area, close to the gypsiferous bedrock and the glacial deposits, may contain gypsiferous rock fragments from which the sulfate is obtained. Data are lacking on this point.

EFFECT OF CIRCULATION IN THE SATURATED ZONE

Wells obtain ground water from depths of about 10 to 400 feet in the Erie-Niagara basin. It can be visualized from figure 9 that shallow wells in recharge areas obtain water of local origin, whereas, wells in discharge areas and wells finished in deep water-bearing zones are likely to obtain water of distant origin. Water of distant origin travels along the deeper flow paths and, therefore, is more likely to come in contact with salt and gypsum at depth, as well as to have passed through different chemical environments.

The chemical analyses indicate that the dissolved-solids content of ground water is increased as it flows through different chemical environments. Undoubtedly, ion-exchange reactions modify the chemical character to some extent but in general, no processes seem to be operating which significantly decrease the overall chemical content of ground water. Sulfate, however, is lost by some deeply circulating ground water in the Appalachian Uplands. Water in the zone of aeration and shallow ground water contain at least 15 ppm of sulfate. Samples from some deeper wells contain less than 1 ppm. The sulfate is probably reduced to hydrogen sulfide on contact with methane by the process described by Hem (1959, p. 103). Noticeable odors of hydrogen sulfide in water from many deep wells substantiate this theory. Also, ground water from many water-bearing zones in shale and from confined sand and gravel aquifers contain a flammable gas, presumed to be methane.

The variation of water quality with depth can be illustrated by comparing the chemical quality of water from wells 239-833-1 and -2 (table 9). The sample from the deeper well is higher in chloride, hardness, and specific conductance as would be expected. The sample from the shallower well has a sulfate content about equivalent to that of precipitation, whereas the deeper well has a sulfate content of only 0.4 ppm. The deeper circulating water entered an environment which not only caused an increase in its total chemical content but caused a selective reduction of sulfate.

A more striking effect of variations in chemical quality related to ground-water circulation can be demonstrated by a sample from well 225-841-1 (table 9) and a sample from Connoisarauley Creek taken on July 4, 1963 (Archer and others, 1968). The water level in the well, a few hundred feet from the stream, is above ground level, indicating that the head increases with depth and that ground water is undoubtedly discharging to the creek. The data are summarized below.

	Well 225-841-1 near Ashford Hollow	Connoisarauley Creek at Ashford Hollow (flow 0.85 cfs)
Sulfate (ppm)	16	18
Chloride (ppm)	242	111
Hardness, as $CaCO_3$ (ppm)	108	218
Specific conductance (micromhos)	1,400	525

Ground water of a quality indicated by the sample from the well discharges to the creek but shallow ground water with a higher hardness and a much lower chloride concentration must also enter the creek. On the basis of the chloride concentration of the samples from the well and the creek at Ashford Hollow, and assuming a chloride concentration of no more than 15 ppm for the shallow ground water, more than half the flow of the creek at that time was provided by ground water of high chloride content. The discharge of deeply circulating ground water of high chloride content in the reach of the stream above Ashford Hollow is, thus, about 250,000 to 300,000 gpd.

Occurrences of highly mineralized water at shallow depth, such as described for Connoisarauley Creek, can be explained in terms of the ground-water circulation, as shown in figure 17. At shallow depth, the saturated zone contains ground water relatively low in dissolved solids. This is water that has gained much of its dissolved solids while passing through the zone of aeration. In recharge areas the ground water flows deeper and out of the shallow zone. Its dissolved-solids content is increased, and it becomes saturated or supersaturated with regard to carbonate minerals in the zone marked "moderately high in dissolved solids." Reduction of sulfate by methane, as described elsewhere, may also occur in this zone. The water flowing downward beneath the highest parts of the hills, enter the deepest part of the circulation system. This water becomes salty either by contacting the buried salt beds in the Camillus Shale or by mixing with very old salty water stored in the rocks (perhaps connate water). It then circulates upward to the central part of the discharge area, the valley bottom. As a result, the ground water at depth in the central part of the valley is high in chloride.

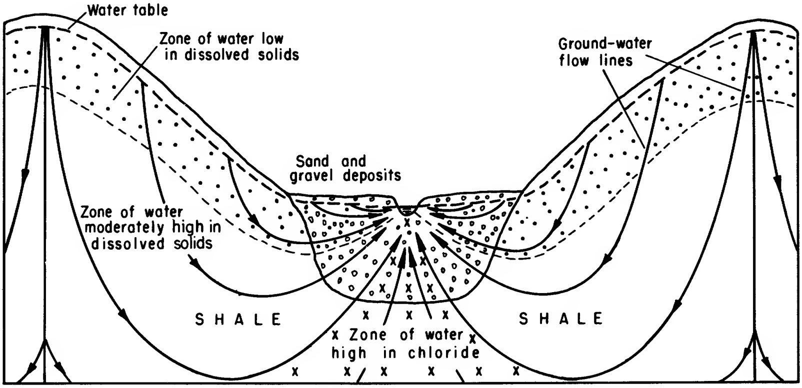
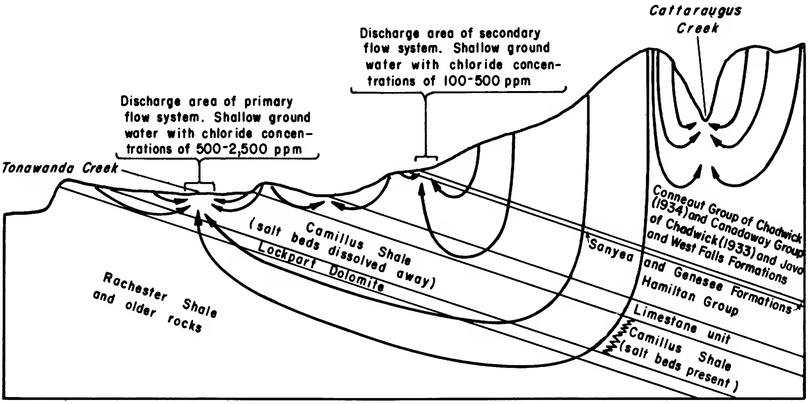


Figure 17.--Variations of chemical quality of ground water as related to the flow system in a valley in the Appalachian Uplands.

A hypothesis of major and secondary regional flow systems can be advanced to explain the concentrations and distribution of sulfate and chloride in ground water shown in plate 5. The belt of chloride concentrations of 100 to 500 ppm that extends through Hamburg and East Aurora (pl. 5) is anomalous as are the areas of extremely high chloride along Tonawanda Creek. Also anomalous is the area that includes Lancaster, Lackawanna and the lake shore near Hamburg where sulfate ranges from 100 to 500 ppm (pl. 5). The rocks in these areas doubtless do not provide these constituents in such concentrations. They certainly do not do so elsewhere along the strike of the rock units. These data indicate flow

systems exist which are controlled by the major topographic features, as illustrated in figure 18. The quality of water at great depth in the area



Ground water circulates through a regional flow system from the Appalchian Uplands to the Erie-Ontario Lowlands and discharges near Tonawanda Creek and through less extensive but nevertheless major flow systems. Probable flow lines are shown. The deepest circulating water may move upward toward Tonawanda Creek through bedding joints in the Camillus Shale and Lockport Dolomite rather than through the underlying rocks.

Figure 18.--Inferred regional circulation of ground water to explain variations in chemical constituents in ground water at shallow depth.

is shown by the analysis for well 250-821-1 (table 9). The concentrations of sulfate and chloride can be explained by the mixing of deeply circulating ground water with less highly mineralized shallow ground water. For example, it is possible that water moving along the deep flow path shown in figure 18 would contain a chloride content of 50,000 to 100,000 ppm and after mixing with ground water of a local flow system could produce the chloride contents of 1,500 to 2,500 ppm in samples from wells in the major discharge area along Tonawanda Creek. Ground water moving along the secondary flow system is likely to be highly mineralized but not to as great a degree as water moving along the deeper flow system. This water mixes with water of a local flow system and produces fairly high concentrations of sulfate and chloride in the secondary discharge area. Numerous abandoned gas wells in the area (Kreidler, 1963) may allow salty water to circulate upward and discharge through leaky casings into the shallow ground water. Data are not available to evaluate this possibility. The boundary of the salt beds shown in plate 5 roughly parallels the boundary of the Appalachian Uplands suggesting a topographic control for this boundary rather than a depositional one. Topography would determine the character of a flow system such as described in figure 18 and subsequent solution and removal of the

salt beds in the northwestern half of the basin. Thus, though pollution of shallow ground water through abandoned gas wells may be occurring, it probably is not the principal cause of the high chloride ground water illustrated in plate 5.

The solubilities of calcite and dolomite in water are increased by the presence of sodium chloride (Hem, 1959, p. 24, 81). This fact may explain the high permeability of the soluble rocks in the discharge areas where chloride is high. Shallow ground water mixing with high chloride water in the discharge areas have their dissolving potentials renewed and widen the water-bearing openings through which they discharge.

EFFECT OF WELLS ON GROUND-WATER QUALITY

Pumping from wells modifies the ground-water flow systems in the vicinity of the wells. This, in turn, may affect the quality of the water pumped. For example, wells in sand and gravel deposits near streams are in the flow paths of ground water that may have originated at a relatively great distance. The ground water may owe little of its character to the sand and gravel around the well. If the well is pumped at a high enough rate, recharge from the stream will be induced. Water in streams is more dilute than adjacent ground water, particularly so when the streams carry overland runoff. Stream water is charged with little carbon dioxide -- unless aquatic growth is severe -- and will dissolve little calcium, magnesium, and bicarbonate by infiltrating the sand and gravel deposit. The quality of ground water pumped from wells inducing stream infiltration is, therefore, likely to improve as pumping continues, until the maximum infiltration rate is reached.

Ground-water pumpage can also cause inferior water to invade a formation. Well 256-844-1 was eventually abandoned because the quality of the water deteriorated. The well probably is finished in the Bertie Limestone of the limestone unit. The analysis dated August 15, 1951, given below, is typical of ground water obtained from limestone. Water from the underlying Camillus Shale intruded the formation in response to pumping and significantly increased the sulfate and chloride concentration of the water produced, as is shown by the analysis for September 17, 1962.

Analysis of water samples from well 256-844-1
(Analyses by Buffalo Testing Laboratories, Inc.)

	August 15, 1951	September 17, 1962
Total solids, ppm	395	878
Sulfate, ppm	a/ 55	138
Chloride, ppm	11	103
Hardness, ppm	237	560

a/ Originally reported as sulfur trioxide.

In the bedrock, wells may provide a hydraulic connection between horizontal water-bearing openings that were formerly unconnected. (See, for example, Johnston, 1964, p. 37-39.) The quality of water in the openings may differ, and the well will produce water of a composite quality. A well may also penetrate openings in which circulation was restricted and in which mineralized water has accumulated. In such a case, the well provides a means to increase circulation and the mineralized water may eventually be flushed out of the openings. Such flushing apparently occurred when wells 308-850-1 and -2 were deepened because the dissolved solids in the water, particularly sulfate, increased at first but then decreased and approached the quality prior to deepening. Where other wells tap two or more discrete water-bearing zones, water from the upper zone, having a higher head flows down the well into the lower zone and forces the more mineralized water away from the well. Unless the well is pumped continuously, the mineralized water is not drawn in. Or, if water in the lower zone has a higher head than that in the upper zone, mineralized water may move up the well into the upper zone.

GROUND-WATER POLLUTION

In this report, the term "ground-water pollution" will be used to designate any increases in chemical constituents, organic or inorganic, caused by man. In general, but not necessarily so, polluted ground water is unsafe or unpleasant for humans to consume. It may, nevertheless, be useful for industrial cooling and process water, air conditioning, or irrigation.

EXISTING POLLUTION

Ground-water pollution in the basin falls into six classes: (1) septic-tank effluent; (2) disposal-well effluent; (3) petroleum and chemical leakage on spillage; (4) salt storage and spreading; (5) use of fertilizers and insecticides; and (6) radioactive waste disposal.

Sewage is released from septic tanks at numerous private dwellings and by far causes the most widespread and troublesome ground-water pollution in the area. Sewage carries microorganisms, some of which are disease causing. Also present in sewage are chloride and nitrogen compounds, and synthetic detergents, which are persistent in the ground. Sewage pollution of ground water is detected by counts of coliform bacteria, some types of which are characteristic of intestinal wastes, and by analyses of chloride, ammonia, nitrite, and nitrate. Chloride introduced by sewage may be masked by the high chloride content of much of the ground water in the area. The nitrogen compounds usually oxidize to nitrate in the ground and generally do not attain sufficient concentrations to interfere with the use of the water. The coliform count of unpolluted ground water is less than 2.2 per 100 milliliter; therefore, a greater count is probably indicative of pollution by sewage.

Ground water polluted by sewage is a problem only if the sewage reaches a well within several hundred feet of its point of release. The bacteria count of the water is reduced by travel through the ground. Chloride and nitrate persist in the ground but are generally not objectionable in themselves and are diluted anyway by dispersion. Most polluted wells for which data were obtained from county health departments or health officers are located within 150 feet of a septic tank or other source of pollution. Wells showing pollution are at scattered locations throughout the area. Most are in rural or suburban settings and are affected by purely local sources, usually a septic tank on the same or adjacent property. However, general pollution is indicated by analyses of ground-water samples in areas adjacent to Java Lake (237-820) and Lime Lake (225-828), in Cowlesville (250-828), and along the strip of land developed for housing extending from Williamsville east to Harris Hill Road (257-840). In addition, because of the density of septic tanks, general pollution of shallow ground water can be assumed to be occurring in all unsewered communities. Sufficient data on ground-water pollution are not available to bear out this assumption because most communities have public water supplies and, therefore, few wells in them have been tested.

Of approximately 750 wells in the area that were tested since 1960 and found to be polluted, more than half had coliform counts greater than 100 per 100 mililiter. This is generally regarded as indicating gross pollution. Some polluted wells were repeatedly sampled and exhibited a wide range of coliform counts. This probably was a result of treatment of the well with chlorine solution between samplings.

The injection of drainage water, and possible injection of industrial wastes through disposal wells produces some ground-water pollution in Buffalo and the surrounding area. In 1951, when an inventory was made, several manufacturing plants were found to use wells to dispose of drainage water. The inventory has not been updated. One educational institution is known to presently dispose of some drainage water into wells. Pollution caused by drainage water is of low concentration, but considerable quantities of water may be involved.

Spillage on the surface or leakage from underground storage tanks of petroleum or chemical products probably has caused some pollution of shallow ground water. Test borings near Scajaquada Creek penetrated petroleum fluids in a sand and gravel deposit. Further data are not available, but areas where such pollution may have occurred are numerous.

The storage and use of salt for controlling ice and snow on roads introduce sodium chloride into ground water. Road salting is known to have affected the potability of water from wells near heavily treated roads in other areas. The data are not conclusive, but road salting may have caused an increase in chloride in ground water at the Clarence and East Pembroke service areas of the New York State Thruway. A sample taken in July 1953 from a well at the Clarence service area had a chloride content of 3.6 ppm (Noel M. Ravneberg, New York State Thruway Authority, written communication, 1953). A sample from the same well taken by the State Health Department in August 1963 had a chloride content of 17 ppm. More concentrated pollution may have occurred at the East Pembroke service area. In 1953, samples from two test wells had chloride concentrations of 1.4 and 11.6 ppm (Noel M. Ravneberg, New York State Thruway Authority, written communication, 1953). A sample taken from the present supply well by the N. Y. State Health Department in August 1963 had a chloride concentration of 90 ppm.

Agricultural chemical fertilizers and insecticides are possible sources of pollution in the area. Nitrate and phosphate are leached from chemical fertilizers and carried to the saturated zone by infiltrating water. Investigations of the effects of modern insecticides on water quality show that minute amounts of these substances may appear in surface and ground water in agricultural areas. Most modern insecticides are extremely stable and, therefore, will be persistent in the ground. Their toxicities on humans have not been determined. Chemical fertilizers and insecticides are used most heavily in the towns of Eden, Collins, Farnharm, and Batavia where intensive farming is practiced.

Radioactive wastes are disposed of by burial at the Western New York Nuclear Service Center at Ashford. Some contamination of ground water in deposits of low permeability are an expected part of the operation. Ground-water supplies are not drawn from the contaminated

deposits nor is it expected that contaminated water will move into permeable deposits.

The movement and persistence of the various pollutants in the ground differ. The concentration of microorganisms in sewage is reduced by sorption on soil and rock particles as it percolates through the zone of aeration. Chloride and nitrate compounds in sewage, road salt, petroleum liquids, and most chemicals are much less changed by travel through the zone of aeration. Sewage, salt, and most chemicals are soluble or miscible in water and enter the flow system. The microorganisms in sewage are further removed as they travel through the saturated zone. The other constituents of sewage and most dissolved pollutants are not decreased but their concentrations are reduced by dispersion. The principles governing the movement of pollutants in the saturated zone away from various types of sources are described by Deutsch (1965). Petroleum liquids and similar low density liquids that are nonmiscible with water, do not move into the flow system. Instead they accumulate at the top of the saturated zone and move extremely slowly down the slope of the water table.

POTENTIAL POLLUTION

The types of activities causing ground-water pollution will tend to increase with the population growth forecast for the basin, possibly except for the use of fertilizers and insecticides. In addition, the trend toward stricter control of surface-water pollution may encourage the disposal of industrial wastes through wells.

AREAS OF HIGH POLLUTION POTENTIAL

Several hydrologic and geologic factors affect the potential for pollution of ground water. With particular reference to sewage pollution, the following factors are enumerated:

(1) Depth to the water table -- the deeper the water table the longer sorption processes have to work.

(2) Character of unconsolidated deposits -- fine-grained material is most effective at sorbing pollutants and also its permeability is low so that travel time is long; sand and gravel deposits have a low sorption capacity and permit rapid drainage and movement through the saturated zone.

(3) Depth to bedrock -- little sorption takes place in the bedrock.

(4) Ground-water gradient -- ground-water velocity increases and, therefore, travel time of the pollutant decreases with increasing gradients.

(5) Nature of the flow system -- this determines the course followed by the pollutant. However, when a pollutant reaches the water table, it may cause a modification of the flow system. A continuous source is hydraulically analagous to a recharge well and causes a mound of the pollutant to build up and move away from the source in all directions.

LeGrand (1964) has developed a "point-count" system for evaluating pollution potential of wastes disposed of to shallow flow systems which takes into account the factors mentioned above. His classification system is applicable to the hydrology of the area and should serve to help evaluate the pollution potential for specific sites.

Two types of terrane in the area have a high potential for pollution: (1) bedrock thinly veneered with glacial deposits, and (2) sand and gravel deposits in valleys. Wherever bedrock is overlain by surficial deposits less than 15 feet thick, sewage from septic tanks will be little reduced in concentration before reaching the water-bearing zones in the rock. This presents a danger to ground-water supplies obtained from any of the rocks in such areas. The greatest danger is to supplies from the soluble rocks because of the horizontally extensive permeable water-bearing zones that lie at shallow depth. Examples of pollution are numerous in the limestone unit and the Lockport Dolomite. These units have a high pollution potential over much of their outcrop area. Both units occur in areas that probably will be intensively developed for housing in the future. The Devonian shale formations underlying parts of the Erie-Ontario Lowlands and the steep hillsides in the Upland also present a pollution potential because of the thinness of the overlying glacial deposits.

The depth to the water table in sand and gravel deposits in valleys is generally 15 to 20 feet or less. Sewage is little reduced in concentration before reaching the water table in such deposits. The danger of pollution is brought home by the present situations around Lime Lake, Java Lake, and in the valley of Eighteenmile Creek near North Boston. Sand and gravel deposits in valleys doubtless will be favored for the construction of housing because their surfaces are flat or gently rolling and drainage for septic wastes is good. Because the sand and gravel deposits offer the best possibilities in the area for developing large quantities of ground water, this pollution potential has an important bearing on future water supplies.

DIRECT DISPOSAL OF WASTES INTO THE SATURATED ZONE

A pollution potential exists if toxic or objectionable wastes are disposed of through wells without due regard for the hydrologic regimen. The chemical data define a major and a secondary deep flow system (fig. 18). Shallower flow systems occur in all the major valleys. Waste water injected into any of these flow systems will eventually reach the surface in a discharge area. The safety of disposal by injection wells depends principally on the type of waste and its persistence. Acid wastes injected into carbonate rock will be neutralized in a relatively short time. Such wastes may be injected into the flow system with safety if

sufficient travel time exists before the waste reaches a supply well or the surface; and if the reaction products of the neutralization are not objectionable. Prudence would demand that even short-lived wastes should not be injected into a rock unit within its outcrop belt.

Some toxic chemicals and high-level radioactive wastes are extremely long-lived in the ground, though their concentrations may be affected by sorption. Such long-lived wastes should be injected only at depths below the active flow system.

The problem of deep disposal of radioactive wastes within the basin was discussed in reports by Colton (1961) and the Subcommittee on Atomic Waste Disposal, American Association of Petroleum Geologists (1964, p. 6-8). The various rock units were evaluated as reservoirs for the disposal of wastes. Because of a lack of data on the head of water at depth, the possibility of the movement of wastes at various depths could not be evaluated. The definition of the flow system made in the present report (fig. 18) indicates that in the extreme southern part of the basin, injection should be below the Camillus Shale and in the northern part of the basin should be at a still lower but undetermined stratigraphic horizon (although not necessarily at a greater depth). Another consideration concerning the depth of disposal is that the rocks of the Albion Group (beneath the Clinton Group) are a valuable source of natural gas and are also used as gas-storage reservoirs. Deep disposal of wastes into the Albion may interfere with gas production and storage.

GROUND-WATER DEVELOPMENT

The scale of an undertaking largely governs the means by which it is attempted. If only small ground-water supplies are needed, reason hardly exists for even thinking about how to go about their development. The wells will be drilled and the springs will be dug out just as they have been in the past. However, if the development of large ground-water supplies is considered, a number of questions arise requiring answers that are in the nature of predictions. The quantity of water available for development can be roughly estimated with little data. The more closely actual development approaches the estimate of the quantity available, the more the estimate must be refined at considerable effort. Even knowing precisely how much water is available is not the end point. Ground water can only be developed to the extent that it can be intercepted before reaching a discharge area. The placement of wells, therefore, must be planned to intercept the water most effectively and economically. The effect of ground-water development on other aspects of the hydrology must be considered. For example, if ground water that ordinarily discharges to streams is intercepted, the streamflow will be reduced. A judgment must be made on the degree of streamflow reduction that can be tolerated.

CONSTRUCTION OF WELLS

The location of most wells in the basin is determined by other than geologic or hydrologic factors. The only choice to be made in the location of most domestic-supply wells is to choose between the front yard and the back yard. Industrial and public-supply wells are also drilled close to where the water is needed. Methods of well construction are tailored to suit conditions at the site.

DUG WELLS

Where the water table is within about 20 feet of the surface in unconsolidated deposits, water supplies can be obtained by dug wells as shown in figure 19, A and B. Dug wells may be used in any unconsolidated deposits, and they are the only type of well that can be successfully used to obtain water from till. They are hydraulically efficient wells because of the large wall area through which water may enter. In deposits of low permeabilities, their large storage capacities of 40 or 50 gallons of water per foot of depth sustain pumpage for short periods at higher rates than the yield of the well. In deposits of high permeabilities, large-diameter dug wells may yield as much as 1,000 gpm. Dug wells are susceptible to pollution by surface water flowing down the annular space around the lining. They should be sealed at the surface, preferably by a concrete apron poured around the top of the casing.

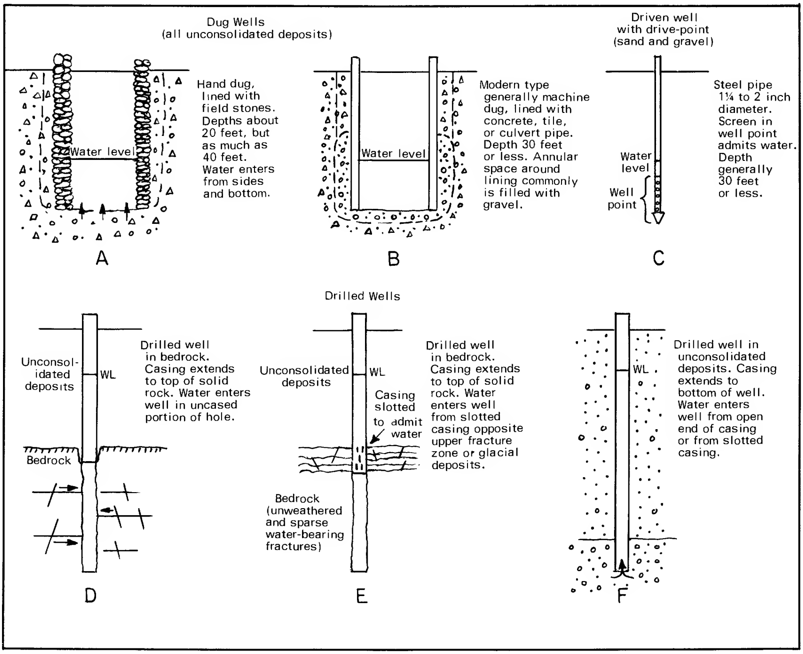


Figure 19.--Types of wells used for domestic water supplies.

DRIVEN WELLS

Driven wells are an economical way of obtaining small water supplies from relatively permeable deposits. Driven wells consist of small-diameter pipe and a steel point that push the unconsolidated material aside as the pipe is driven into the ground (fig. 19, C). The well point is commonly 3 feet long and contains either perforations with gauze screen or a wire-wrapped screen. Because of the small wall area of the perforations, a well point will produce a sufficient supply only if it is finished in a permeable sand or sand and fine gravel deposit. Because of its small

diameter, generally 2 inches or less, a driven well must be pumped by suction and, therefore, the pumping lift cannot be more than about 25 feet.

DRILLED WELLS

Most wells in the area are drilled with cable-tool rigs and finished in bedrock. The unconsolidated deposits above the bedrock are held in place with a steel casing, usually 6 inches in diameter. The casing is seated a short distance into the bedrock by driving. After the casing is seated, an uncased hole is drilled in the bedrock in order to (hopefully) intersect one or more water-bearing openings (fig. 19, D). If the yield provided from the rock is insufficient, the casing may be pulled back slightly so that water from the unconsolidated deposits may enter the well. Some wells have the casing slotted a short distance near its lower end to admit water from the weathered and fractured zone at the rock surface or from the glacial deposits (fig. 19, E).

Small to moderate supplies of water can be obtained from sand and gravel deposits by means of open-end drilled wells (fig. 19, F). These wells are cased the entire length and water enters from the bottoms of the casings. In some of these wells the casing is slotted with a burning (welding) torch in order to admit water.

If large supplies of water are required from sand and gravel deposits, drilled wells are constructed which are screened in coarse-grained permeable beds. Figure 20 shows construction details of the most common types of screened wells. The well screens used are made of corrosion resistant metals, and the width of the slots is carefully controlled during manufacture. The lengths of the screened sections in wells in the area vary from 10 to 40 feet, and the diameters generally range from 8 to 16 inches. A screen presents a large wall area for the entrance of water, and, to take full advantage of this, fine-grained material is removed from around the screen. In most wells in the area, a gravel pack (fig. 20, A) is used to keep fine material away from the well screen. In other wells, the slot size is selected so that the fine material in the formation will be drawn through the screen and pumped out of the well during development, leaving the coarse-grained material to settle around the screen (fig. 20, B).

EVALUATION OF PRESENT DEVELOPMENT

Development of ground water has made possible the construction of public water-supply systems at a number of communities. The communities, source of water, and average use as of 1963 are given in table 5. The data on water use are approximate.

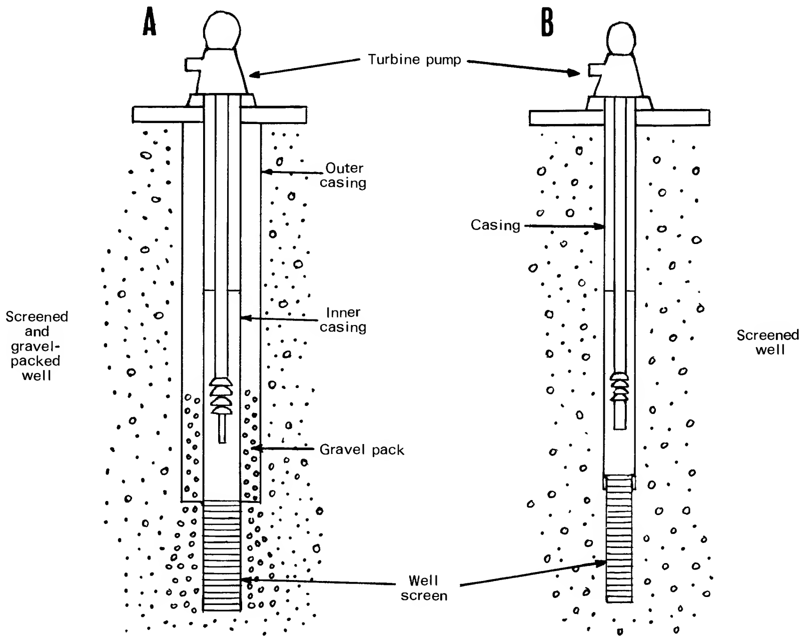


Figure 20.--Types of wells used to obtain large supplies from sand and gravel deposits.

The supply wells of several systems listed in table 5 are in sand and gravel deposits with a high potential for further development. Recharge of the deposits far exceeds withdrawals from the wells of Arcade, Batavia, Chaffee, Collins, North Collins, and Springville. Withdrawals at Springville, for instance, are less than the recharge received on 1 square mile of a deposit several square miles in area. The deposits at Batavia are not only extensive but are heavily recharged. An underflow conduit through which ground water moves from Tonawanda basin to the Genesee basin lies east of the well field in the body of sand and gravel deposits that extends to Seven Springs Ponds (pl. 4). The public-supply wells at Batavia may be in a position to intercept some of this water.

So-called springs provide water supplies for Cattaraugus, Delevan, Lawtons, Machias, North Java, Otto, Varysburg, and West Valley. Some of these are truly springs, that is, natural surface seeps that have been developed. Others are infiltration galleries that intercept water moving

Table 5.--Development of ground water for public water supplies in the Erie-Niagara basin

Community	Source 1/	Average use (gallons per day)
Alden	253-829-3, 254-829-1, -2, -3	200,000
Arcade (includes Sandusky)	229-822-1, -2 231-825-2 232-825-1	700,000
Batavia	259-809-2, -6	1,000,000
Cattaraugus	Four areas of springs, 3 mi south to southeast of village and 219-851-1	200,000
Chaffee	233-828-1	15,000
Collins	229-856-1 230-856-1	50,000
Collins Center	229-849-1, -2	25,000
Corfu	257-824-1	60,000
Delevan	Numerous springs, 1 mi southwest of village, including 228-829-1Sp, -2Sp	50,000
East Aurora	246-836-1, -2, -3, -4	750,000
Gowanda	227-856-1	100,000
Holland	238-832-1, -2	80,000
Lawtons	Several springs including 232-855-1Sp	10,000
Machias	Springs south of village	50,000
North Collins	234-856-1, -3, -4, -5	250,000
North Java	Infiltration galleries and well 240-819-1	15,000
Otto	Infiltration gallery about 1 mi south of village	5,000
Springville	230-840-2, -3	400,000
Varysburg	Springs 1 mi east of village and 246-818-1	25,000
West Valley	Infiltration galleries including 223-836-1, -2	35,000

1/ Well or spring number is given for those sources that were inventoried during the study and are listed in tables 6 and 7.

a few feet below the surface. Such sources are not efficient for developing large supplies. They salvage only water that is about to be discharged and, therefore, must be spread out for a considerable distance through the discharge area. It is difficult to divorce the discussion of "spring" sources from the transmission systems, most of which were constructed while the technology of well construction was primitive. They probably offered the best alternative to the use of wells or surface-water reservoirs at the time. The systems entail rather long pipelines for the quantity of water produced. But the pipeline represents the only significant capital investment, and operating costs are low because the flow of water is by gravity. The present "spring" sources and systems fulfill their purpose but do not offer the possibility of developing significant additional water supplies. Development of springs must be spread through a large area, and the pipelines do not seem adequate to transmit any large increase in supply.

The possibility of additional supplies by means of wells for the communities presently served by springs is good. Delevan, Machias, and Lawtons sit on or near exposed sand and gravel aquifers of large potential that can be tapped by screened wells. An antiquated well (219-851-1) and pumping equipment of the Village of Cattaraugus, which are little used, indicate the availability of a large supply in a buried sand and gravel aquifer there. Sand and gravel deposits east of North Java probably would be a source of additional water, though the deposits have not been tested for large supplies. A buried sand and gravel deposit at Varysburg is indicated by the supplemental supply well 246-818-1. This well was designed to produce only 50 gpm, but the aquifer may be able to provide considerably larger supplies. A buried sand and gravel aquifer lies in the broad flat valley northeast of Otto, as is tapped by a number of domestic wells, such as 222-848-1 and -2. Screened wells in this aquifer may produce high yields, and testing is warranted when additional supplies are required. West Valley has occasional water shortages because the present "spring" source is insufficient. The sand and gravel deposits extending north and south from Beaver Siding offer the possibility of additional supplies but have not been tested. Well 224-836-1 may indicate a buried aquifer, worth testing, beneath the community.

The ground-water supplies at Alden, Collins Center, and Corfu are limited. Development of the aquifer at Corfu is handicapped because wells will not yield more than 100 gpm due to the small saturated thickness of the deposits. The yield of the deposits at Alden probably is restricted to the rate of recharge by direct infiltration, about 300,000 gpd per square mile. Some induced infiltration probably can be obtained from the streams, but not a significant amount because of the low permeability of the streambeds. The Collins Center supply probably can be expanded several times that of the present small use of 25,000 gpd, but the aquifer is of small extent and the recharge is limited to that from direct infiltration.

The sand and gravel aquifer in which the wells of East Aurora are located is thick but of limited areal extent. Water is discharged to the small streams draining it. The aquifer could potentially be developed to stop the ground-water discharge to these streams. Probably at least 300,000 gpd in addition to the present supply could be developed. Sand

and gravel deposits in the valley of Buffalo Creek upstream from East Aurora may provide an additional water source in the future.

Gowanda and Holland obtain public water supplies from buried sand and gravel aquifers. The supply at Holland can be expanded over the present small use, but the potential supply cannot be estimated because the recharge to the deposits is unknown. The deposits along Buffalo Creek downstream from Holland represent an additional source of supply. The aquifer in which the Gowanda public-supply well is finished has been over-developed to the extent that water levels have declined from a static level of 7 feet above ground level in 1928 to a level of 150 feet below land surface in 1963. Yield of the public-supply well has declined from 500 gpm to about 200 gpm. Part of this decline in yield may be caused by a decrease in well efficiency due to deterioration of the well screen. The remainder of the decline is doubtless due to the dewatering of the aquifer. Additional ground-water supplies for Gowanda are available north of the village from the sand and gravel deposits between Clear and Cattaraugus Creeks and from possible buried sand and gravel deposits south of Gowanda near Dayton.

In addition to public supplies, well systems also furnish large water supplies for industrial use. Large supplies from sand and gravel deposits are obtained at Gowanda by the Moench Tannery Division of the Brown Shoe Corp., and at Batavia by the O-AT-KA Milk Products Cooperative. The two wells (227-856-3 and -4) of Moench Tannery produce about 500,000 gpd and are finished in the aquifer tapped by the Gowanda public-supply well. The O-AT-KA well (259-809-1) that is presently used is near the public-supply wells of the city of Batavia. It has a yield of 1,400 gpm and daily pumpage from it is as much as 1,000,000 gallons.

The Camillus Shale provides large industrial supplies of cooling water at, and north of Buffalo. The Wurlitzer Corp. pumps 500,000 gpd from well 303-850-2; Dunlop Tire and Rubber, 600,000 gpd from wells 258-855-1, -2 and -3; Durez Division, Hooker Chemical Corp., about 1,000,000 gpd from wells 302-851-2 and -3; and E. I. du Pont de Nemours & Co., Inc., adjacent to the Dunlop Tire and Rubber Co., pumps a large, but undetermined, quantity of water from wells. Development of ground water from the Camillus Shale near the Niagara River probably can be considerably increased because infiltration can be induced from the river. Wells near Buffalo also are in a discharge area toward which there is natural ground-water movement.

An abandoned gypsum mine in the Camillus Shale serves as a source of cooling water for the Carborundum Company plant and the wallboard plant of Bestwall Gypsum Co. near Akron. Total pumpage from the mine ranges from 700,000 to 1,000,000 gpd.

The limestone unit provides a number of smaller industrial and commercial supplies for cooling in Buffalo. Development of the limestone unit for large supplies is limited by the well yields that can be obtained. Well yields of 300 gpm may be obtained at places but 100 gpm is more usual. Large unused sources of water are the quarries in the limestone unit. Pumpage of 3,000 gpm from the quarry near Harris Hill, east of Williamsville, is necessary to keep the quarry dewatered. This is a potentially valuable supply for industrial use.

The number of individual domestic wells can be greatly increased. There is a limit to how closely these wells may be spaced. In the areas underlain by till, lake deposits and shale, recharge is not known but may be on the order of 50,000 gpd per square mile. Assuming that 500 gpd will be pumped from each domestic well, and that all recharge can be salvaged, a perennial supply cannot be assured if the density of wells in a recharge area is greater than 100 wells per square mile. If sufficient undeveloped land lies up the hydraulic gradient from the developed area, a greater concentration of wells is possible without exceeding the perennial yield. Theoretically, the density of domestic wells in sand and gravel aquifers may be about 10 times greater than in the less permeable aquifers, because recharge to sand and gravel aquifers is 500,000 gpd or more. The above calculation is presented as a guideline only.

POTENTIAL DEVELOPMENT

The most outstanding broad feature of the ground-water resources of the basin is the distribution of extensive and thick sand and gravel aquifers. The greatest potential for ground-water development in these deposits exists in a peripheral belt of the area that extends from Springville westward through the Cattaraugus basin and northward through the Tonawanda basin to Batavia. The present degree of development barely skims the surface of these resources. Particularly noteworthy among these subsurface reservoirs are the sand and gravel deposits drained by Spring Brook at Springville, Hosmer Brook at Sardinia, Elton Creek upstream from Elton, Lime Lake Outlet, Cattaraugus and Clear Creeks upstream from Arcade, and Tonawanda Creek between Attica and Batavia.

The peripheral belt of sand and gravel deposits occurs in the part of the Erie-Niagara basin that is most distant from and considerably higher in altitude than Lake Erie. It is, therefore, the most difficult part of the basin to supply with water from the lake. Fortunately, the presence of the sand and gravel deposits makes this area self-sufficient in water supply. In combination with Lake Erie and the stream systems of the area, they offer the possibility of developing an integrated water supply and distribution system for the Erie-Niagara basin.

DESIGN AND SPACING OF WELLS

In locating and designing well fields, consideration must be given to the hydraulics of wells and to the character of the flow system including the position of recharge and discharge areas. Hydraulics is concerned with the effects produced on the water levels and head in an aquifer by wells. It is also concerned with the flow mechanics of water moving into or out of a well. The methods of ground-water hydraulics are artificial in that actual field conditions are approximated by idealized mathematical formulas or physical analogies. The most powerful tool of ground-water hydraulics, the Theis nonequilibrium equation (Theis, 1935) was developed by assuming that the flow of water in an aquifer toward a discharging well is analogous to the flow of heat in a

plate-shaped conductor of infinite extent toward a perpendicular rod in contact with the plate. Despite what may seem a far-fetched approach, the Theis equation works for extensive aquifers. Coefficients of transmissibility and storage can be computed from the equation on the basis of rather short periods of discharge from an aquifer and concurrent observations of water-level changes in the aquifer. Once the coefficients of transmissibility and storage are determined, the effect on water levels caused by extended periods of pumping can be computed. The Theis equation has been extensively modified so that it may be applied through a broad range of hydraulic conditions. (See, for example, Bentall, 1963a, 1963b, and Ferris and others, 1962.)

Of importance in the Erie-Niagara basin is the concept of hydraulic boundaries. In discussing flow systems, streams were described as discharge areas. It was also recognized that water moves from the till and shale into the sand and gravel deposits. In the hydraulics of wells, because ground-water pumpage creates new gradients much steeper than natural gradients, some additional concepts are used. In the parlance of hydraulics, a sand and gravel deposit in a valley would be crossed by a recharge boundary (the stream draining it) and bordered by an impermeable boundary (the valley wall of till and shale). A recharge boundary feeds water into the cone of depression and retards drawdown. At an impermeable boundary, water does not flow toward the cone of depression and the drawdown is much increased. If a well is available for observing drawdown around a pumping well, the distances to hydraulic boundaries can be computed. In order to compute both the distance and direction of the boundaries from the pumping well, three observation wells generally are needed. Once the distances to hydraulic boundaries are known, the effects of the boundaries on water levels around the pumping well can be computed by the theory of images.

In the theory of images, imaginary wells or streams that cause the same hydraulic effect are substituted for the hydraulic boundaries. For example, the effect of an impermeable boundary on a discharging well can be duplicated by an imaginary well on the opposite side of the boundary but with the same discharge and at the same distance from the boundary as the real well. A number of special solutions of image-well problems have been published. (See Ferris and others, 1962, p. 144-166, for a discussion of image theory.) Of special note for predicting drawdowns due to pumping is a chart for the computations of drawdown developed by Theis (in Bentall, 1963b, p. 10-15), which can be used for boundary conditions such as occur in the study basin.

The effects of boundaries provide a general rule for locating large-yield wells so as to keep drawdowns and, therefore, pumping costs to a minimum. Wells should be spaced parallel to hydraulic boundaries. They should be as distant as possible from impermeable boundaries and as close as possible to recharge boundaries. For most sand and gravel deposits the rule can be easily applied because recharge boundaries (streams) and discharge boundaries (shale and till at the valley wall) are easily discernible. If the streams are minor, go dry periodically, or are not connected to the aquifer, wells should be placed in the thickest part of the aquifer. To capture the maximum amount of ground water possible,

the natural movement of water must be considered. Wells should be located as far down gradient in the flow system as possible, particularly so in aquifers with relatively small ground-water storage. The optimum spacing of wells depends greatly on the cost of piping and electrical connections as well as operating costs. It can be computed by a formula developed by Theis (in Bentall, 1963b, p. 113-115) that makes use of cost estimates as well as aquifer characteristics.

The design of individual wells in sand and gravel deposits depends on the character of the water-bearing material and the planned yield. For a particular well the diameter, length of screen, size of screen opening, and size and diameter of gravel pack, if used, are determined from the size distribution of the water-bearing material according to standards developed by experience in constructing such wells. Standards and techniques vary among individual consultants and well-drilling firms. A review of well-design criteria that can be applied to the Erie-Niagara basin is given by Walton (1962, p. 28-29).

METHODS OF INCREASING RECHARGE AND CONTROLLING STORAGE

According to Todd (1959, p. 1), artificial recharge consists of direct methods -- injection of water through wells and pits and the spreading of water on the surface -- and indirect methods -- the inducing of infiltration from streams and lakes. Induced infiltration has already been discussed, and it was pointed out that it is presently being obtained in some parts of the area. Such indirect recharge can be obtained by wells finished in sand and gravel deposits that are crossed by streams.

Before discussing direct methods of artificial recharge, some characteristics of ground-water reservoirs in the area should be considered. The ground-water reservoirs can fill up only to levels that are controlled by the streams draining them. The excess recharge that is received is rejected and flows away to the streams. Optimum development of a ground-water reservoir is accomplished when pumping reduces water levels sufficiently to stop ground-water discharge to streams and creates space in which to store recharge so that it will not be rejected and can be pumped out later. For an extensive sand and gravel aquifer with a specific yield of 0.2, a storage space about 10 feet thick is required to store an average annual recharge of 1 mgd per square mile. Water levels would probably have to be pumped down an average of more than 10 feet to sufficiently reduce the gradient to retain this water in storage. Direct methods of artificial recharge make sense only when an aquifer approaches optimum development and room is available to store the recharge water. Exposed sand and gravel deposits would be most effectively recharged through shallow pits, by water spreading, and by retention of overland runoff in stream channels by small dams. The use of recharge wells in sand and gravel deposits is complicated by the treatment needed for the recharge water to avoid clogging the well. Clogging is brought about by even a low concentration of turbidity or by the precipitation of chemical constituents on the well screen. Recharge wells are the only means, however, of artifically recharging the buried sand and gravel deposits, such as the deposit

at Gowanda that has been overdeveloped for public and industrial supplies.

The limestone unit, Camillus Shale, and Lockport Dolomite have low storage coefficients and artificial recharge may be required where these units are heavily developed. They can be recharged through unscreened wells with little treatment of the recharge water.

Possibly some ground-water reservoirs may best be used as aids in controlling surface-water runoff. The sand and gravel deposits around Freedom in the valley of the tributary of Clear Creek serve as an example. A dam across this valley would retain overland runoff which would infiltrate into the sand and gravel deposits and discharge at a slow rate to the stream farther down the valley.

CONCLUSIONS

The best sources of ground water in the area are exposed sand and gravel deposits distributed in the Cattaraugus Creek basin and in the Tonawanda Creek basin south of Batavia. Less extensive (but potentially productive) sand and gravel aquifers lie along Eighteenmile Creek, East Branch Cazenovia Creek, and Buffalo Creek. The water available in these deposits is on the order of 50 million gallons per day without considering the potential available from induced stream infiltration or the increased recharge that might be brought about by large withdrawals. The sand and gravel deposits with the largest potential are distributed through the part of the area most distant from and considerably higher in altitude than Lake Erie. They, therefore, are a ready source of water for the part of the area most difficult to serve from present distribution systems drawing water from the lake.

Large supplies of ground water, 500 to 1,000 gpm from individual wells, can be obtained from the Camillus Shale. Still larger supplies probably could be pumped from abandoned gypsum mines near Akron and operating mines near Clarence Center. The quality of water from the Camillus is poor and the water would be useful mainly for industrial uses, such as cooling.

The Onondaga Limestone will provide supplies of 100 gpm in many parts of its outcrop belt and occasional supplies of as much as 300 gpm. The quarry near Williamsville will provide a supply of about 3,000 gpm from inflowing ground water.

Small supplies are available from the remaining bedrock units and glacial deposits throughout the area. However, a small percentage of the wells drilled in shale in the southern half of the area have yields that are inadequate for a domestic supply.

RECOMMENDATIONS

If ground-water development in the area continues at the pace prevailing over the past 20 years, additional areal studies will not be required in the foreseeable future. On the other hand, the planning of large-scale withdrawals should be based on quantitative studies of specific ground-water reservoirs. The investigations should include (1) test drilling to determine the thickness and lithology of the deposits and the feasibility of constructing large-yield wells, (2) pumping tests of wells to determine the aquifer constants, (3) flow measurements of streams recharging and draining the deposits, and (4) observations of water-level changes in the aquifer through at least 1 year. To provide a base for short-term hydrologic observations that may be necessary for intensive quantitative studies, water-level observations should be made on a continuing basis in several wells in the basin.

Data on public-supply wells drilled in the future should be obtained routinely by the New York State Conservation Department as part of the Department's regulatory duties. Data should include construction details of the wells, logs of materials penetrated, pumping-test information, and analyses of water. Similar data should be obtained for test wells. This information will make possible further evaluations of the aquifers of the basin at little cost or trouble.

Evaluation of potential pollution from deep-well disposal of wastes requires information on the circulation of water at depth. The only feasible way in which this information can be obtained is by measurement of water levels in wells being drilled to natural-gas or oil reservoirs. Possibly arrangements can be made by the Conservation Department with the State Geological Survey and drilling contractors to obtain such water-level measurements when wells are drilled in the future. Samples for chemical analyses of deep ground water should also be obtained from gas or oil wells as they are drilled.

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GLOSSARY OF GROUND-WATER TERMS AND ABBREVIATIONS USED IN THE TEXT OF THIS REPORT

Term or abbreviation	Definition
Altitude	Distance, in feet, above mean sea level.
Aquifer	A formation, group of formations, or part of a formation that is water bearing.
cfs	Cubic feet per second.
Cone of depression	The depression, roughly conical in shape, produced in a water table by pumping from a well.
Confining bed	One which, because of its position, and its impermeability or low permeability relative to that of the aquifer, prevents or retards the natural discharge of water from the aquifer into adjacent formations.
Dip	The angle between the bedding plane and the horizontal plane.
Drawdown	The vertical distance through which the water level in a well is lowered by pumping from the well at a given rate.
gpd	Gallons per day.
gpm	Gallons per minute.
Ground-water discharge	Discharge of water from the zone of saturation, usually to streams or other surface-water bodies, but may include the discharge from wells.
Ground-water recharge	Water that is added to the zone of saturation.
Ground-water runoff	That part of the runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.
Head	Amount of water pressure at a certain point. The amount of pressure is determined by the height of the water over that point.
Hydraulic gradient	Pressure gradient. As applied to an aquifer it is the rate of change of pressure head per unit of distance of flow at a given point and in a given direction.
Hydrograph	A graph showing level, flow, velocity, or other property of water with respect to time.
Impermeable	Having a texture that does not permit water to move through it perceptibly under the head difference usually found in subsurface water.
Infiltration	The flow or movement of water through the soil surface into the ground.
Infiltration capacity	The maximum rate at which the soil, when in a given condition, can absorb falling rain or melting snow.
Joint	Fracture planes or surfaces that divide rocks but over which there has been no visible movement.
mgd	Million gallons per day.
Permeability (P) (coefficient of)	The rate of flow of water in gallons a day (gpd) through a cross section of 1 square foot under a hydraulic gradient of 100 percent at a temperature of 60°F.
Porosity	The ratio of the aggregate volume of pore spaces in a rock or soil to its total volume. It is usually stated as a percentage. (Porosity is equal to the sum of the specific yield and the specific retention.)
Safe yield	The rate at which water can be withdrawn from an aquifer without depleting the supply to such an extent that continued withdrawal at this rate is harmful to the aquifer itself, or to the quality of the water, or is not economically feasible. In practice, the safe yield is equal to or less than the mean annual recharge to the aquifer.
Screen loss (of a well)	That part of the drawdown in a pumping well that may be attributed to the restriction to free flow of water through the screen and the material immediately surrounding the screen.
Soil (zone)	A layer of loose earthy material, approximately parallel to the land surface, which has been so modified and acted upon by physical, chemical, and biological agents that it will support plant growth.
Specific capacity (of a well)	The ratio of the yield of a well to the drawdown of water level in the well at a given pumping rate; generally expressed in gallons per minute per foot of drawdown.
Static level (Hydrostatic level)	That level which, for a given point in an aquifer, passes through the top of a column of water that can be supported by the hydrostatic pressure of the water at that point. Corresponds to the water table or piezometric surface under static conditions.
Storage (S) (coefficient of)	The volume of water in cubic feet released from storage in each vertical column of an aquifer having a base 1 foot square when the water table or other piezometric surface declines 1 foot. (This is approximately equal to the specific yield for non-artesian aquifers.)
Stream infiltration	The flow or movement of water through the bed of a stream into the underlying material
Transmissibility (T) (coefficient of)	The rate of flow of water in gallons per day through a section of aquifer 1 foot wide and having a height equal to the saturated thickness of the aquifer, under a hydraulic gradient of 100 percent, and at a temperature of 60°F. The coefficient of transmissibility is equal to the coefficient of permeability times the saturated thickness of the aquifer.
Water table	The upper surface of a zone of saturation.
Zone of aeration	The zone between the water table and the land surface in which the pore spaces of the rocks are not all filled (except temporarily) with water.
Zone of saturation	The zone in which the pore spaces of rocks are saturated with water under hydrostatic pressure.

Table 6.--Records of selected wells in the Erie-Niagara basin

Well number: See "Well-Numbering and Location System" in text for explanation.

Year completed: a - about
b - before

Type of well: Drl - drilled
Drv - driven

Depth of well: All depths below land surface.
a - about
r - reported
all others measured

Diameter of well: Diamaters of dug wells are approximate.
Where two or more sizes of casings were used, they are shown in descending order.

Depth to bedrock: All depths below land surface
a - about
m - measured
all others reported

Water-bearing material: Gravel, sand, silt, and till - glacial deposits of Pleistocene age.
Camillus Shale - Camillus Shale of Silurian age.
Limestone - limestone unit consisting of the Onondaga Limestone of Devonian age and the Bertie Limestone and Akron Dolomite of Silurian age.
Lockport Dolomite - Lockport Dolomite of Silurian age.
Shale - Hamilton Group and Conneaut Group of Chadwick (1934) and intervening units, all of Devonian age.

Altitude above sea level: Estimated from topographic maps to nearest 5 feet.

Water level: All water levels are below land surface except those preceded by a (+) sign, which are above land surface.
a - about
p - pumping effect is probable
Flow - water flows above land surface but static head could not be measured.
r - reported
all others measured by U.S.G.S. personnel

Method of lift: AL - air lift
Dw - deep well cylinder pump
Jet - deep well jet pump
Sub - submersible pump
Sw - shallow-well pump
Tur - turbine pump

Type of power is indicated as -- I - internal combustion engine
M - manual
all others are electrically powered

Estimated pumpage: Average daily pumpage supplied by owner, tenant, or operator, or computed on basis of per capita consumption of 50 gpd per person or 20 gpd per milk cow.

Use: A - abandoned
Ag - agricultural
C - commercial
D - domestic
F - dairy farm
GT - gas test
I - industrial
In - institutional
Ir - irrigation only
PS - public supply
T - test
U - unused
X - destroyed

Remarks: anal - chemical analysis in this report
dd - drawdown
est - estimated
gas - flammable gas issues from well
gpd - gallons per day
gpm - gallons per minute
H_2S - hydrogen sulfide gas present in ground water
iron - water has noticeable iron content
LS - land surface
OW - observation well, series of water-level measurements available
r - reported
swl - static water level
temp - temperature, in degrees Fahrenheit, measured by U.S.G.S. on same day wate level was measured unless otherwise noted

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
217-851-1	Cattaraugus	T. Borrowdale	a1900	Dug	15.1	30	--	Sand	1,410	8.9	5-15-63	--	--	A	
218-843-1	do.	E. Alexander	1943	Drl	r39.5	8	--	Sand and gravel	1,520	Flow	5-13-63	--	7,000	F	Anal; temp 50; flows perennially, estimated as 5 gpm, 0.5 ft above LS; water-bearing zone 0.5 ft thick (r).
219-843-1	do.	F. Telaak	a1948	Drl	81.5	6	--	do.	1,500	p4.1	5-14-63	Sw	1,900	F	Anal.
219-851-1	do.	Village of Cattaraugus	a1934	Drl	r218	8	--	Gravel	1,260	Flow	5-15-63	AL	--	PS	Anal; H_2S; temp 50.0; yield 200 gpm (r); flow 40 gpm, 3 ft below LS; rarely used.
220-845-1	do.	C. Minekime	b1943	Drl	r90	6	--	Sand and gravel	1,355	+20	5-14-63	--	3,500	F	Anal; temp 50.2; flows 2.5 gpm from faucet 3 ft above LS; used for cooling milk only.
220-846-1	do.	C. Lang	a1920	Drl	r96	4	--	do.	1,340	Flow	5-14-63	--	3,500	F	Anal; temp 49.8; flow 2.5 gpm from discharge pipe in milk room continuously.
220-847-1	do.	do.	a1950	Drl	135	6	--	Sand	1,340	+9	5-14-63	--	5,500	D	Anal; temp 49.8; flows 3.8 gpm, 3 ft above LS; well is cased to 152 ft and partly filled in by sand entering at bottom (r); blue clay overlies water-bearing sand (r).
220-850-1	do.	L. Gregory	a1955	Drl	67.2	6	a25	Shale	1,240	11.8	5-15-63	--	--	A, D	Anal; inadequate yield for domestic supply.
221-841-1	do.	R. Weishan	1962	Drl	163	6	--	Sand	1,920	69.5	4-29-63	--	--	C	Yield 10 gpm bailer test (r); drilled to supply campsite under construction at time of visit.
-2	do.	--	--	Dug	2.8	30	--	Sand and gravel	1,840	.5	5- 2-63	--	50,000	A, F	Anal; temp 44.4; flow 37 gpm from lateral discharge pipe 2.8 ft below LS.
221-849-1	do.	J. Frank	1961	Drl	r135	7	105	Shale	1,340	p67.7	5- 5-63	Sub	100	D	Anal; iron; yield 6 gpm bailer test (r).
222-848-1	do.	R. Stevens	1959	Drl	r315	6	--	Gravel	1,330	p+1.5	5-22-63	Sub	1,500	F	Anal; temp 50; clay, silt, and very fine sand overlie water-bearing gravel (r).
-2	do.	R. Minekime	1960	Drl	r374	6	374	do.	1,340	p+.9	5-22-63	Sub	1,500	F	Anal; iron; gas; temp 49.0; flow 0.25 gpm, 0.8 ft above LS.
223-836-1	do.	West Valley Crystal Water Co.	--	Drl	r230	6	130	Shale	1,600	16.4	7-22-63	--	--	A	Anal; sand 0-130 ft (r); never used because yield is insufficient for requirements.
-2	do.	do.	--	Dug	6.0	--	--	Sand and gravel	1,605	4.9	7-22-63	--	14,000	PS	Anal; temp 48.2; flow 10 gpm (est) from lateral discharge pipe 4.9 ft below LS; concrete casing is 3.3 X 5 ft in dimension; 1 of 3 similar so-called "springs" which are source of company's supply.
223-847-1	do.	R. Wisocki	1962	Drl	r255	7	--	Gravel	1,345	r+1	12-62	Sw	2,000	F	Anal; iron; gas; yield 32 gpm, dd 21, Dec. 1962 (r); gray clay overlies water-bearing pebble gravel (r); shallow water-bearing gravel at 16 ft depth yielded 12 gpm, but was cased off.
223-848-1	do.	D. Dankert	1948	Drl	r438	8	450	do.	1,340	Flow	5-21-63	Jet	1,500	F	Anal; gas; temp 50.2; flows 1.5 gpm (est), 1 ft below LS; cased to 438 ft, drilled to 450 ft but casing would not drive.
-2	do.	H. Tegler	1952	Drl	r300	7	>425	do.	1,340	rFlow	9-52	Sw	2,500	F	Anal; gas; water level was higher than 20 ft above LS 9-52 (r); flows when not pumped; drilled 425 ft in glacial deposits; casing set at 300 ft; silt and clay overlie water-bearing gravel.
224-836-1	do.	West Valley School District	--	Drl	r360	--	--	--	1,540	--	--	Tur	--	In	Anal; H_2S.
224-838-1	do.	H. Feldman	1961	Drl	88	6	68	Shale	1,760	p56.3	11- 7-61	Jet	--	F	Yield 15 gpm bailer test (r).
224-848-1	do.	R. Hebner	a1960	Drl	r438	8	--	Sand and gravel	1,360	--	--	--	--	D	

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
224-850-1	Cattaraugus	E. Ball	1950	Drl	r78	6	15	Shale	1,700	r40	1961	Jet	100	D	Water-bearing zone is near bottom of well (r).
225-836-1	do.	C. Conrad	--	Drl	78	6	m71	do.	1,460	7.7	7-22-63	--	--	A, F	H_2S; formerly used for watering cattle; water was pumped by hand.
225-838-1	do.	R. Codd	--	Drl	r250	5	--	do.	1,450	r15	1961	Sub	1,500	F	Yield 10 gpm (r); dd 145 ft (r).
225-839-1	do.	S. Kwiclen	--	Drl	22.6	24	--	Till	1,660	21.0	12- 8-60	Sw M	100	D	Abandoned drilled well in shale, 140 ft deep on same property.
225-840-1	do.	M. Skinner	--	Dug	11.9	48	11.9	do.	1,845	3.9	4-21-62	Sw	--	D	
225-841-1	do.	L. Barbati	1964	Drl	148	7	118	Shale	1,415	Flow	9-17-64	--	900	C	Anal; temp 51.7; flow 0.6 gpm, 2 ft above LS; yield 10 gpm bailer test.
226-825-1	do.	Kirkby	1927	Drl	156	8	24	do.	1,690	Flow	6- 5-64	AL	7,000	U, C	Anal; temp 48.0; flow 5 gpm (est) 0.6 ft below LS.
226-827-1	do.	--	--	Dug	36.7	40	--	Sand and gravel	1,720	35.2	6- 5-64	Dw M	--	A	
226-836-1	do.	B. Hadley	--	Dug	11.9	36	9	Till; shale	1,450	4.1	4-30-62	Sw M	20	D	
226-837-1	do.	S. Heary	--	Drl	92.4	6	--	Shale	1,570	58.4	4-28-62	Jet	1,200	F	
-2	do.	P. Simko	--	Dug	14.7	36	--	Sand and gravel	1,420	p7.7	4-30-62	Sw	--	D	
226-838-1	do.	State of New York	--	Drl	37.5	3	--	Till	1,280	24.0	12- 1-60	Dw M	--	A	
-2	do.	do.	--	Drl	219	6	--	--	1,350	182.7	11- 2-61	--	--	A	
-3	do.	do.	1961	Drv	22	4	--	Till	1,380	10.0	10- 9-61	--	--	A	OW.
-4	do.	do.	1962	Drv	21	1 1/4	--	Sand and gravel	1,380	7.3	4-27-62	--	--	T	Anal; 19 ft of till overlies sand and gravel; screened from 18 to 21 ft.
-5	do.	do.	1961	Drv	11	1 1/4	--	Till	1,380	10.1	10-20-61	--	--	T	Anal.
226-839-1	do.	do.	--	Dug	6.1	24	--	Sand and gravel	1,450	4.3	12- 8-60	Sw	--	A	Anal; temp 40.5, 4-19-62.
-2	do.	do.	--	Dug	16.5	36	--	Till	1,490	10.7	12- 8-60	Sw M	--	A	
-3	do.	do.	--	Dug	11.4	30	--	do.	1,400	9.5	12- 8-60	Sw	--	A	Anal; OW.
-4	do.	do.	1960	Drl	156	7	103	Shale	1,395	91.5	10-16-61	--	--	A	Anal; yield 12 gpm bailer test (r); OW.
-5	do.	do.	--	Dug	19.4	38	--	Till	1,770	13.0	4-27-62	--	--	A	
226-840-1	do.	Cyro	--	Dug	17.8	36	17.8	do.	1,780	10.2	4-20-62	Sw M	--	A	
-2	do.	G. Rachic	--	Dug	5.3	24	5.3	do.	1,800	2.8	4-21-62	Sw	200	D	
226-851-1	Erie	F. Colligan	1962	Drl	r137	6	a85	Shale	1,240	25.9	5-24-63	Jet	250	D	Anal; yield 5 gpm bailer test (r); silt and fine sand overlie shale.
227-826-1	Cattaraugus	Baldwin	1962	Drl	r80	6	a40	do.	1,610	r10	10-62	--	250	D	
227-828-1	do.	H. Herman	--	Drl	33.5	5	--	Sand and gravel	1,620	32.0	6- 5-64	--	--	A	Well may be partly backfilled.
227-837-1	do.	Frank Green	--	Drl	r90	6	--	Shale	1,515	Flow	4-30-62	Sw	--	D	Water flows over top of casing, 1 ft above LS.
-2	do.	H. Kester	1957	Drl	r166	6	164	do.	1,500	9.1	11- 8-61	Jet	--	D	
-3	do.	E. Zimmerman	1961	Drl	r100	6	a90	do.	1,510	5.8	5- 1-62	Sub	--	F	Yield 14 gpm bailer test (r).
-4	do.	State of New York	--	Drl	169	6	--	--	1,540	147.2	11- 3-64	--	--	A	
227-838-1	do.	C. Zeffers	e1940	Drl	161.3	6	--	Shale	1,450	24.3	5- 1-62	--	1,000	F	

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
227-838-2	Cattaraugus	State of New York	1962	Drv	11	1 1/4	--	Till	1,370	2.1	4-19-62	--	--	T	Anal; screen, 8-11 ft.
227-839-1	do.	do.	--	Dug	16.6	30	--	do.	1,560	6.7	4-18-62	--	--	A	
-2	do.	do.	1961	Drl	r112	6	110	Shale	1,580	56.0	4-18-62	--	--	A	Yield 20 gpm bailer test (r).
-3	do.	do.	--	Dug	15.9	36	--	Till	1,430	2.4	4-28-62	--	--	A	
-4	do.	do.	1961	Drl	160	7	a80	Shale	1,410	82.9	4-18-62	--	--	F, X	Well also drew from unconsolidated deposits overlying shale; yield about 5 gpm (r).
227-840-1	do.	R. Custer	--	Dug	10.1	24	10.1	Till	1,730	4.1	4-21-62	--	--	D	
-2	do.	L. Cobo	a1930	Drl	r40	6	15	Shale	1,555	4.5	4-20-62	Sw	--	F	Yield is inadequate for farm; a drilled well 70 ft deep is used along with this well.
-3	do.	--	--	Drl	41	4	--	do.	1,525	19.2	10-21-61	Dw M	--	A	
-4	do.	R. Miller	--	Drl	48.5	6	--	do.	1,525	6.5	4-21-62	--	--	A	
-5	do.	E. Carl	1947	Dug	6.4	24	--	Till	1,560	1.0	4-26-62	Sw	--	D	
227-851-1	Erie	C. Johnson	--	Dug	17.6	24	--	Sand and silt	1,330	9.3	5-24-63	--	--	A	Temp 44.8; domestic supply is obtained from a spring downslope from well; an attempt to drill a well was abandoned because only fine-grained materials were penetrated for considerable depth.
227-852-1	do.	Ross	1962	Drl	33.0	6	--	Sand and gravel	1,280	13.0	5-24-63	Sw	2,000	F	Anal; gravel was placed at bottom of well by driller (r).
227-856-1	Cattaraugus	Village of Gowanda	1928	Drl	r376	12, 8	377	do.	780	p152.4	4- 4-63	Tur	300,000	PS	Anal; gas; temp 55.0, 2-20-63; shutter screen 8-inch diameter, 6-gage, from 336-376 ft; gravel packed; when drilled swl was +7 ft and yield was 550 gpm with dd of 92 ft (r); yield 210 gpm, pumping water level 186 ft on 2-20-63 after redevelopment of well; generally pumped from May to October (estimated pumpage is for this period).
-3	do.	Moench Tanning Co. Division of Brown Shoe Co.	1934	Drl	r329	18, 12	--	do.	790	--	--	Tur	200,000	I	Gas; Armco iron screen, 12-inch diameter, 6-gage, from 299 to 329 ft; gravel packed; yield was 275 gpm on 8-31-62 after redevelopment (r); yield when drilled was 585 gpm (r).
-4	do.	do.	1948	Drl	r332.5	18, 12	--	do.	790	p192	2-18-63	Tur	300,000	I	Gas; screen, 12-inch diameter from 302.5-332.5 ft; gravel packed; yield 510 gpm, swl 141.7 ft, dd 39.4 ft on 12-14-48; periodic redevelopment necessary to maintain yield.
-5	do.	do.	1963	Drl	r350	8	347	do.	790	200	11-27-63	--	--	T	
-6	do.	Village of Gowanda	a1920	Drl	r299.5	7	--	do.	795	176.3	11- 3-64	--	--	A, PS	Anal; gas; temp 56.2, 1-17-63; yield about 20 gpm.
228-827-1	do.	H. Herman	a1958	Drl	r110	8	--	Sand	1,500	17.9	6- 5-64	Jet	200	D	Drilled to 115 ft but cased only to 110 ft (r).
228-837-1	do.	A. Nisita	--	Drl	83.1	6	--	Shale	1,465	26.2	10-23-61	--	--	A	
-2	do.	do.	--	Drl	41.5	8	--	do.	1,560	9.5	10-23-61	Dw M	--	A	
228-838-1	do.	M. Falt	--	Drl	16.2	20	--	Sand and gravel	1,410	10.6	10-21-61	Sw	--	D	H_2S.
-2	do.	S. Emerson	1960	Drl	r130	6	80	Shale	1,360	--	---	Sub	--	F	Yield 5 gpm (r).
-3	do.	E. Hansen	--	Drl	61.7	5	--	do.	1,410	9.5	10-24-61	Dw M	--	U	
-4	do.	G. Smith	1960	Drl	73.0	6	65	do.	1,490	50.5	11- 7-61	Sub	--	D	
-5	do.	R. Codd	--	Dug	16.4	36	--	Till	1,475	11.8	5- 1-62	--	--	A	

Table 6.--Records of selected wells in the Lake Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
228-839-1	Cattaraugus	F. Waterstram	--	Dug	11.0	48	--	Sand and gravel	1,330	9.0	10-21-61	Sw	--	F	
228-840-1	do.	F. Felton	a1958	Drv	12.4	1 1/4	--	do.	1,280	p10.0	10-24-61	--	--	A	About 1 ft away from driven well used for farm supply.
-2	do.	H. Kelley	--	Drl	53.1	6	--	Shale	1,370	p12.4	4-20-62	Jet	--	D, Ag	Iron; supplies a chicken farm.
-3	do.	French	1961	Drl	54.4	6	32	do.	1,370	3.9	4-20-62	--	--	U	Yield 3 gpm bailer test (r).
228-846-1	Erie	D. Bylbie	1955	Dug	8.6	24	--	Sand and gravel	1,230	6.8	5-29-63	Sw	450	D	Anal; temp 48.0.
228-851-1	do.	B. Skuse	1932	Drl	r110	6	--	Shale	1,120	--	--	Jet	1,500	F	Anal; iron.
228-857-1	Cattaraugus	Seneca Nation of Indians	1964	Drl	298	8	78	do.	870	111.3	8-26-64	--	--	A	Gas; yield less than 1 gpm (r); "shot" with 39 sticks of dynamite which did not improve yield.
-2	do.	do.	1964	Drl	447.6	8	a70	do.	870	442.7	8-26-64	--	--	A	Temp 55.4; yield is negligible; "shot" with 39 sticks of dynamite which did not improve yield.
229-819-1	do.	Earl Thomas Estate	a1920	Drl	37.9	6	--	Sand and gravel	1,820	21.6	5-13-64	Dw M	--	A	OW.
-2	do.	do.	--	Dug	35.0	36	--	do.	1,820	21.0	5-13-64	--	--	A	Goes dry.
-3	do.	C. Owens	1947	Drl	39.2	6	--	do.	1,815	20.4	5-15-64	Jet	100	D	Anal; perennial supply.
229-822-1	do.	Village of Arcade	1954	Drl	r75.9	18, 12	--	do.	1,660	r23.5	10-11-54	Tur	600,000	PS	Screen, 12-inch diameter, 100-slot, from 65.9-75.9 ft; gravel packed; yield 425 gpm; on initial test, swl 21.0 ft, dd 30.5 ft; pumpage rate is prior to addition of well 231-825-2 to Arcade system.
-2	do.	do.	--	Drl	r54	12	--	do.	1,660	--	--	Tur	15,000	PS	Screen; yield 60 gpm; supplies community of Sandusky.
229-841-1	Erie	R. Gentner	--	Dug	16.6	24	--	do.	1,360	13.3	5- 7-64	Sw	--	F	
229-842-1	do.	do.	1959	Drl	r325	6	--	--	1,340	--	--	--	--	A	Dry hole; sand and gravel 0-15 ft; clay and sand 15-325 ft; filled with trash.
229-846-1	do.	D. Kessler	1953	Dug	11.0	30, 12	--	Sand	1,400	2.0	5-29-63	Sw	200	D	Anal; temp 46.0; yield about 10 gpm pump test.
229-849-1	do.	Town of Collins, Water District No. 3	1959	Drl	r60	10, 6	--	Sand and gravel	1,220	Flow	--	--	40,000	PS	Flows about 30 gpm through header 3 ft above LS into main of water system; flow provides sufficient supply for weekdays; screen, 6-inch diameter, 100-slot, 51-60 ft.
-2	do.	do.	1959	Drl	r56	18, 10	--	do.	1,220	Flow	--	Tur	--	PS	Iron; screen, 18-inch diameter, 100-slot, 51-56 ft; gravel packed; yield 150 gpm; generally pumped only on weekends.
229-856-1	do.	Town of Collins, Water Districts Nos. 1 & 2	1959	Drl	r35	18, 10	--	do.	820	r19	4-16-58	Tur	--	PS	Screen, 18-inch diameter, 100-slot, 30.3-35.3 ft; gravel packed; pumping test, 150 gpm, dd 9.5 ft.
229-857-1	do.	M. Gates	1964	Drl	r42	6	--	Sand	820	31	9-14-64	--	--	D	Screen, 5-inch diameter, .030-slot, 32-42 ft; yield 10 gpm bailer test with no appreciable drawdown.
230-829-1	Cattaraugus	W. Delaney	1962	Drl	r244	8, 6, 4	--	Gravel	1,400	r+30	2-11-63	--	3,000	F	Anal; H_2S; supplies house and barn by artesian pressure; when drilled flow was 200 gpm, estimated by driller.
230-833-1	Erie	E. Korowski	1954	Drl	56.2	6	--	Sand	1,265	40.6	8- 5-64	Jet	100	D	Anal.
230-835-1	do.	R. King	1955	Drl	57.8	6	--	Sand, silt, clay	1,245	a2	8- 5-64	--	--	A	Yield is inadequate for domestic supply.
-2	Cattaraugus	W. Winkey	--	Dug	20.2	36	--	Sand and gravel	1,390	17.9	8- 6-64	Sw	--	F	
230-837-1	Erie	L. Rumfola	a1941	Drl	33.7	6	--	Gravel	1,365	14.7	8- 5-64	Sw	3,500	F	Anal; cased to 40 ft; partly backfilled with crushed stone.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
230-838-1	Erie	B. Mooney	--	Drv	14.1	1 1/4	--	Sand and gravel	1,380	3.8	5- 6-64	--	--	A	OW.
230-840-1	do.	Village of Springville	1931	Drl	r139	18, 6	--	do.	1,350	16	7-31	--	--	A, PS	Originally finished with shutter screen, 12-inch diameter from 121-135 ft; pumping test 830 gpm, dd 25 ft; gravel packed liner with 6-inch diameter screen from 119.5-135 ft, then installed to reduce amount of sand pumped from well; abandoned about 1944 because of sand pumping.
-2	do.	do.	1944	Drl	r137	18, 12	--	do.	1,350	pr27	1-29-63	Tur	200,000	PS	H_2S; pumping rate 630 gpm; screen, 12-inch diamater from 122-137 ft; gravel packed; pumping test on 8-5-44, 672 gpm, swl 27.4 ft, dd 16.4 ft after 8 hours pumping (swl at this time probably was affected by pumping from wells 230-840-1 and -3).
-3	do.	do.	1942	Drl	r159	18, 10	--	do.	1,350	p31.5	1-29-63	Tur	200,000	PS	H_2S; pumped at 600 gpm; screen, 10-inch diameter, 100-slot from 144-149 ft; 80-slot from 149-159 ft; gravel packed; pumping test 5-14-42, 513 gpm, swl 37.7 ft, dd 20.6 ft (swl probably affected by pumping of well 230-840-1).
230-842-1	do.	G. Kroll	1962	Drl	125	6	19	Shale	1,335	p46	7-28-64	Jet	200	D	Anal; iron; yield 1 gpm (r).
230-843-1	do.	C. Hunt	1964	Drl	r330	6, 4	--	Sand	1,385	199	8-11-64	--	--	O	Yield 5 gpm (r); casing backfilled with washed gravel to 310 ft.
230-845-1	do.	F. Schue	1961	Drl	37.9	6	--	Gravel	1,390	20.6	8-28-64	Sw	200	O	Yield 5 gpm.
230-856-1	do.	Town of Collins, Water Districts Nos. 1 & 2	1948	Drl	r42	18, 10	--	do.	835	r17	1948	Tur	--	PS	Pumping rate 150 gpm; construction details are reported to be similar to those of well 229-856-1.
-2	do.	Dan Gernatt Gravel Products, Inc.	a1956	Drl	r36	--	--	Sand and gravel	830	--	--	Tur	100,000	I	Anal; supplies gravel plant, use is seasonal; yield 400 gpm.
-3	do.	do.	1962	Drl	30.3	18	--	do.	840	3.7	8-12-64	Tur	2,000	I	Anal; supplies cleaner at asphalt plant, use is seasonal; casing perforated from 26-30 ft; pumping test, 150 gpm, swl 4 ft, dd 7 ft.
231-825-1	Wyoming	Village of Arcade	1962	Drl	r50	12	--	Gravel	1,490	r16	3-26-62	--	--	T	Screen and gravel pack, 38-48 ft; pumping test, 150 gpm, swl 16 ft, dd 3.
-2	do.	do.	1962	Drl	r49	20, 12	--	Sand and gravel	1,490	r17	11-28-62	Tur	--	PS	Screen, 12-inch diameter, 100-slot, 39-49 ft; gravel packed; pumping test 500 gpm, swl 17 ft, dd 7.1 ft after 24 hours pumping.
231-830-1	Cattaraugus	M. Schaper	1956	Drl	200	6	--	do.	1,355	10.5	8- 7-64	Jet	300	D	On same property two wells, 60 ft deep, penetrated clay and were dry; a well 400 ft deep flowed but yielded sulfurous water and was destroyed.
-2	do.	C. Kims	1959	Drl	450	6	454	do.	1,375	Flow	8- 7-64	Sub	3,000	F	
231-831-1	Erie	W. Schiener	1962	Drv	r22	1 1/4	--	do.	1,410	--	--	Sw	400	D	
231-833-1	do.	A. Zisser	1964	Drl	280	6, 4	--	Sand	1,390	8.1	8- 5-64	Sub	--	D	Yield 2 1/2 gpm (r).
-2	do.	J. Rung	1959	Drl	59.3	6	--	Gravel	1,430	39.7	8- 5-64	Jet	350	D	Anal; yield about 25 gpm bailer test.
-3	do.	C. Butler	1962	Drl	94.4	6	--	do.	1,430	p47.2	8- 5-64	Jet	3,000	F	Iron; cased to 150 ft (r, driller); yield 25 gpm bailer test when drilled; yield was inadequate in summer 1964; well may be partly filled in with sand entering at bottom of casing.
231-835-1	do.	P. Schuster	1958	Drl	99.7	6	--	Sand and gravel	1,445	p90.8	8- 6-64	Sub	100	D	Anal.
231-838-1	do.	G. Loncasty	--	Drv	17.6	1 1/4	--	do.	1,400	3.5	5-12-64	--	--	A, Ag	Screened from 14.9-17.6 ft; OW.
231-839-1	do.	K. Ploetz	1956	Drl	29.0	6	--	do.	1,400	18.8	5- 6-64	Jet	200	D	

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
231-844-1	Erie	H. Kobler	1961	Drv	12	--	--	Sand and gravel	--	--	--	Sw	150	D	Iron.
231-858-1	do.	Seneca Nation of Indians	1964	Drl	288	8, 6	--	--	810	--	--	--	--	T	Casing stuck in hole; sand, 0-130 ft; sandy clay, 130-230 ft; sand and gravel, 230-288 ft.
-2	do.	do.	1964	Drl	385	8	366	Shale	810	94	3-65	--	--	D	Water-bearing zone at 370 ft; pumping test, 23 gpm, dd 156 ft.
231-900-1	Cattaraugus	do.	1964	Drl	76.9	8	50	do.	715	31.1	8-12-64	--	--	D	Bailer test, 25 gpm, swl 35 ft, dd 25 ft (r).
-2	do.	do.	1964	Drl	76.1	8	49	do.	715	29.8	8-12-64	--	--	D	Do.
232-825-1	Wyoming	Village of Arcade	1953	Drl	r53	12, 8, 10	--	Sand and gravel	1,480	--	--	Tur	650,000	PS	Anal; screen, 10-inch diameter, 100-slot, from 44-49 ft; gravel packed; pumping test of 11-53, 305 gpm, swl 7.1 ft, dd 6.9 ft.
232-827-1	do.	do.	1961	Drl	r149	10, 8, 6	--	do.	1,460	Flow	--	--	--	X, T	Temp 49 (r) 8-16-61; screen, 6-inch diameter, 125-slot, 139-144 ft; flow 60 gpm (r); pumping test 185 gpm, water level 29.7 ft after 24 hours pumping.
232-828-1	Erie	K. Wertz	1958	Drl	28.7	6	--	Gravel	1,435	18.3	6-25-64	Sw	--	C	
232-830-1	do.	N. Hogan	1963	Drl	175	6	--	Sand and gravel	1,405	11.4	8-11-64	Sub	150	D	Anal; H_2S.
232-831-1	do.	P. Loggans	1961	Drl	r87	r6	--	do.	1,435	r32	--	Jet	100	D	Anal.
232-838-1	do.	R. Schweikert	a1963	Drl	129	6	--	Sand	1,430	32.6	5- 5-64	--	--	D	
232-839-1	do.	F. Knowlton	--	Dug	21	30	--	Sand and gravel	1,400	17.7	5- 7-64	--	--	A	Well has been partly backfilled by owner.
232-857-1	do.	Seneca Nation of Indians	1964	Drl	r76	8	14	Shale	845	5.8	8-12-64	--	--	O	Original depth 48.1 ft; no improvement in yield after deepening; yield 7.5 gpm bailer test; cased to 27 ft because of caving shale; water enters at bottom of casing.
-2	do.	do.	1964	Drl	50.8	8	16	do.	840	6.1	8-12-64	--	--	D	Gas; caving shale; casing slotted from 27-30 ft and set into shale and gravel packed.
-3	do.	do.	1964	Drl	55.7	8	16	do.	845	6.3	8-12-64	--	--	D	Gas; yield 1.5 gpm bailer test; water enters from caving shale at 28 ft.
-4	do.	do.	1964	Drl	r148	8	14	do.	--	--	--	--	--	A	Yield less than 2 gallons per hour.
233-828-1	do.	Chafee Water Works, Inc.	a1900	Drl	20.4	8	--	Sand and gravel	1,460	13.5	2-11-63	Sw	15,000	PS	Pumping rate is about 100 gpm.
-2	do.	Greatwood	1960	Drl	50.7	6	--	Sand	1,435	20.0	6-25-64	Sub	100	D	Yield 40 gpm.
233-838-1	do.	Miller	1963	Drl	86.5	6	45	Shale	1,455	18.6	5- 7-64	--	--	A	Yield is a few gallons per minute.
-2	do.	do.	1963	Drl	55.6	6	--	Sand and gravel	1,450	29.0	5- 7-64	--	--	F	
-3	do.	do.	1960	Drl	101.9	6	--	Shale	1,460	46.6	5-12-64	--	--	A, F	Insufficient yield; OW.
-4	do.	R. Wiede	1959	Drl	126.3	6	--	do.	1,440	24.0	11- 8-64	Jet	150	D	Anal; iron; H_2S; can be pumped dry.
233-839-1	do.	J. Buzak	1963	Drl	r528	7	--	Gravel	1,430	r200	4- 3-63	Sub	250	O	Anal; gas; iron.
233-840-1	do.	D. Zittel	1960	Dug	r18	24	--	do.	1,435	r16	--	Sw	4,000	F	Use includes 2,000 gpd for cooling.
233-844-1	do.	J. Pharner	--	Drl	55.5	6	--	Shale	1,470	27.0	7-28-64	--	--	O	
234-823-1	Wyoming	W. Lewandowski	a1935	Drl	r3,403	12	--	Shale?	1,600	Flow	--	--	2,000	GT	Anal; gas; salty taste; temp 53.8, 5-4-64; flow 1-2 gpm, 6.5 ft above LS, 5-4-64; water is presumed to enter well through break in casing at relatively shallow depth.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
234-830-1	Erie	Iroquois Gas Corp.	1964	Drl	--	12	112	Lockport Dolomite	1,465	--	--	--	--	GT	Anal; water collected from a water-bearing zone in Lockport Dolomite at 2,728 ft on 3-7-64; yield from this zone, 0.5-1 gpm; shallow water-bearing zone at 117-126 ft in shale, swl 25 ft.
234-840-1	do.	L. Turner	1957	Drl	130	6	--	Shale?	1,230	14.1	7-31-64	--	--	D	Anal; H_2S.
-2	do.	F. Sixt	--	Dug	7	20	--	Sand and gravel	1,210	p1.0	8-27-63	--	·1,400	D	Anal; temp 56; continuous flow of 1 gpm through syphon.
234-846-1	do.	D. Warner	1950	Drl	55	6	--	Gravel	1,250	Flow	--	Sw	250	D	Anal; temp 52.0, 8-27-63; flow 1 gpm, 5 ft below LS, 8-27-63; clay overlies gravel; maximum use 750 gpd.
-2	do.	E. Strickland	--	Dug	6	60	--	Sand and gravel	1,290	Flow	--	--	2,000	F	Anal; gravity flow of 15 gpm.
234-856-1	do.	Village of North Collins	1914	Dug	32	144	--	do.	810	15.4	1-10-63	Sw	--	PS	Used intermittently during summer; pumping rate 150 gpm.
-2	do.	do.	1936	Drl	41.5	16	--	do.	800	10.1	1-10-63	--	--	A, PS	Reported that screen collapsed.
-3	do.	do.	1956	Drl	r35	24, 12	--	do.	800	r10.7	5-29-56	Tur	--	PS	Used intermittently during summer; screen, 25-35 ft; pumping test 254 gpm, swl 10.7 ft, dd 19.3 ft after 8 hours pumping (r).
-4	do.	do.	--	Drl	ra35	--	--	do.	795	--	--	--	--	PS	Screen; gravel pack.
-5	do.	do.	a1962	Drl	ra35	--	--	do.	795	r5	1-10-63	--	150,000	PS	Screen; gravel pack; pumping rate 350 gpm, dd 18 ft after about 3 hours pumping.
235-826-1	Wyoming	J. Kirchmeyer	a1940	Drl	43	6	--	Shale	1,710	Flow	--	--	--	A	Drilled through bottom of dug well; on 6-19-64 slight flow 1 ft below LS; water level in dug well 3.3 ft below LS.
235-830-1	Erie	A. Petrone	1959	Drl	25.2	6	--	Gravel	1,440	16.6	8-12-64	Sw	150	D	Anal; iron.
235-831-1	do.	N. Raymond	1940	Drl	33.8	6	34	do.	1,500	10.0	8-12-64	Jet	--	U	
235-837-1	do.	N. Feltz	1962	Drl	88.3	6	--	Sand and gravel	1,415	15.1	12- 8-64	Jet	2,500	F	Anal; H_2S.
235-842-1	do.	D. Laurie	1961	Drl	r99	6, 4	--	Gravel	1,030	Flow	--	Sw	4,000	D	Anal; gas; temp 50.8, 8-28-63; flow 3 gpm 0.4 ft above LS, 8-28-63.
235-848-1	do.	H. Bettinger	1959	Drl	37.8	6	19	Shale	1,200	8.7	8-27-63	Sw	200	D	Anal.
235-904-1	do.	Village of Farnham	1953	Drl	r55	10	--	do.	640	--	--	Tur	--	U, PS	Yield about 20 gpm (r); nearby abandoned well entered rock at 18 ft.
-2	do.	do.	1934	Drl	r52	10	--	Sand and gravel?	620	--	--	Tur	--	U, PS	Yield about 20 gpm (r).
-3	do.	Great Lakes Canning Co.	1947	Drl	r42	6	--	Sand and gravel	620	--	--	Sub	20,000	I	Iron; yield 30 gpm (r).
236-828-1	do.	J. Pempsell	1961	Drl	60.2	6	--	do.	1,410	28.59	6-25-64	Jet	200	D	
236-829-1	do.	Erie County Highway Dept.	1958	Drl	r100	6	--	do.	1,330	Flow	--	Sw	--	In	Flow 2.5 gpm.
236-830-1	do.	Buffalo Area Council, Boy Scouts of America	a1960	Drl	r200	6	--	do.	1,260	Flow	--	Sw	5,000	In	Anal; flow 3-4 gpm (est) 5 ft below LS; yield 60 gpm (r).
236-839-1	do.	Kissing Bridge Corp.	1959	Drl	r70	6	--	do.	1,230	Flow	--	Sub	--	C	
-2	do.	Sharp	1961	Drl	100	6	--	do.	1,205	36.3	7-31-64	Jet	100	D	Iron; cased to 130 ft (r).
-3	do.	L. Meacham	a1952	Drl	115	6	--	do.	1,195	Flow	--	Sw	>550	D	Anal; gas; iron.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
236-842-1	Erie	--	1953	Drl	200	6	--	Sand	1,030	Flow	--	--	--	D	Gas; bailed 50 gpm, pumping level 35 ft.
236-843-1	do.	M. Emerling	1958	Drl	51.5	6	--	Sand and gravel	990	29.7	8-22-63	Jet	350	D	H_2S; yield 6 gpm (r).
-2	do.	A. Smith	1954	Drl	r113	6	--	do.	1,020	p1.5	8-22-63	Sw	300	D	Anal; gas; iron, temp 50.3; flow was 75 gpm 8 ft above LS when drilled; flowed above LS until 1959; flow of 1 gpm entering well pit around outside of casing.
-3	do.	N. Anderson	1933	Drl	r87	6	--	do.	1,000	p+7.9	8-22-63	Sw	3,000	D	Anal; iron; temp 53.1; flow 2 gpm, 2.1 ft above LS.
-4	do.	A. Near	1956	Drl	r148	6	--	do.	990	+24	8-22-63	--	3,000	D	Anal; iron; temp 51.2; swl +34 ft when drilled (r); flow 90 gpm, 1 ft above LS when drilled; flow 2 gpm (est), 1 ft below LS, 8-22-63.
236-848-1	do.	R. Mertle	1940	Dug	19	180	3	Shale	980	11.4	8-26-63	Sw	350	D	Anal.
236-849-1	do.	G. Bettinger	1953	Drl	27.4	6	--	Sand and gravel	970	15.7	8-26-63	Sw	300	D	Anal; casing is slotted at 26 ft; yield 28 gpm (r).
237-825-1	Wyoming	R. Miller	1934	Drl	37.2	6	--	do.	1,540	24.6	6-24-64	--	--	A	
-2	do.	L. Woolley	a1933	Drl	24.8	6	--	do.	1,520	19.4	6-24-64	Sw	2,000	F	
237-843-1	Erie	C. Blesy	1958	Drl	86.4	6	--	do.	985	32.0	8-22-63	Jet	300	D	Gas; iron.
237-850-1	do.	E. Remiszewski	1957	Orl	r65	6	11	Shale	860	r8.5	8-26-63	Jet	100	D	Anal; gas; iron; H_2S; yield less than 1 gpm which is reported to be increased by a vacuum-pump device attached to the well.
238-823-1	Wyoming	J. Leonard	1955	Drv	18.4	1 1/4	--	Sand and gravel	1,520	11.7	7-17-63	Sw	150	D	Anal.
238-828-1	Erie	L. Cooper	1953	Drl	r55	6	43	Shale	1,365	r6	--	Sw	100	D	Iron.
NO 238-832-1	do.	Village of Holland	1932	Drl	r210	12, 8	198	Sand and gravel	1,150	r30	--	Tur	--	PS	Gas; iron; H_2S; may enter bedrock; capacity of pump, 300 gpm (r); dd 33 ft after 24 hours pumping; this well and well 238-832-2 yield a combined total of 75,000 gpd (r).
NO -2	do.	do.	1932	Drl	r210	12, 8	198	do.	1,150	r30	--	Tur	--	PS	Gas; iron; H_2S; may enter bedrock; capacity of pump, 160 gpm; located 6 ft from well 238-832-1.
238-841-1	do.	B. Andrezjewski	1957	Drl	r75	6	15	Shale	1,050	8	--	Jet	100	D	Iron; yield 2 gpm.
238-844-1	do.	W. Devitt	1962	Drl	20.8	6	--	Sand and gravel	920	9.6	8-21-63	Sw	250	D	Anal; gas; iron; 15 ft of clay above fine gravel (r); yield 8 gpm.
-2	do.	--	1963	Drl	18.9	6	--	do.	905	6.1	8-21-63	--	--	U	Gas; yield 6 gpm (r).
-3	do.	M. Emerling	a1960	Drl	71.7	6	m27	Shale	955	13.4	4-27-64	--	--	A	OW.
-4	do.	A. Schultz	--	Drl	48.2	6	--	Sand and gravel	920	12.3	4-27-64	--	--	A	OW.
-5	do.	E. Cary	1960	Dug	15.5	42	--	do.	900	5.7	4-27-64	Sw	300	D	
-6	do.	W. Jensen	a1860	Dug	11.0	40	--	do.	900	6.3	4-27-64	--	--	A	OW.
238-851-1	do.	V. Rasmussen	1962	Drl	60.5	10	m14	Shale	840	15.5	8-16-63	Sub	100	D	H_2S; some water enters well around bottom of casing; yield 10 gpm (r).
238-855-1	do.	Town of Eden	1936	Drl	r57	16, 10	--	Sand and gravel	775	1.3	8-10-36	Tur	--	U	Screen, 10-inch diameter, 47-57 ft (r); pumping test 130 gpm, dd 42.7 ft after 8 hours pumping (r).
-2	do.	do.	1946	Drl	r24	24, 12	--	do.	775	4.5	9-19-46	Tur	--	U	Screen, 12-inch diameter, 18.5-24 ft; pumping test 137 gpm, dd 12.6 ft after 8 hours pumping (r).
239-823-1	Wyoming	L. Hoyt	1962	Drl	45.2	6	--	do.	1,500	18.8	7-17-63	Jet	150	D	Anal.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
239-823-2	Wyoming	P. George	1954	Drl	87.2	8	--	Sand and gravel	1,440	Flow	--	Sub	3,000	F	Bailed 30 gpm with slight dd; flows about 1 gpm, 1.4 ft above LS.
239-826-1	do.	F. Minkle	1958	Drl	r46	6	22	Shale	1,180	r25	6-59	Jet	150	D	Anal; gas.
-2	do.	--	--	Drl	108	6	--	Sand and gravel	1,085	Flow	--	--	--	D	Gas; iron; temp 55.0, 6-24-64; slight flow 0.8 ft above LS.
239-833-1	Erie	E. King	1964	Drl	r150	6	--	do.	1,045	+1.4	11-12-64	--	--	D	Anal; gas; temp 51.5.
-2	do.	do.	--	Dug	24.1	36	--	do.	1,045	20.3	11-12-64	Sw	150	D	Anal.
-3	do.	R. Wells	1935	Drl	r135	6	--	do.	1,055	--	--	Sw	--	C	Anal; gas; flows in spring.
239-841-1	do.	J. Zier	1957	Drl	61.2	6	--	Shale	1,025	13.6	8-12-64	Sw	200	D	Anal; H_2S; iron.
239-843-1	do.	G. Frantz	--	Drl	42.2	6	--	do.	1,590	2.12	4-27-64	--	--	A	Yield is inadequate to supply cattle barn; well was never used.
239-844-1	do.	Town of Boston	1961	Drl	r126	6	--	Sand and gravel	910	8.5	4-27-64	Sw	--	In	Gas.
239-845-1	do.	J. May	1954	Drl	r212	6	--	do.	885	Flow	--	Sw	1,500	D	Anal; gas; iron; yield 20 gpm; flow <1 gpm, 1.3 ft above LS, temp 56.2, 8-21-63.
-2	do.	E. Dinse	1962	Drl	15.3	30	--	do.	860	3.9	4-27-64	--	--	A	Iron; OW.
239-852-1	do.	G. Kraft	1955	Drl	r80	6	4	Shale	1,005	a44	8-16-63	Sub	300	D	Gas; iron.
239-853-1	do.	Town of Eden	1956	Drl	r54	30, 12	--	Sand and gravel	810	r5.6	8-24-56	Tur	--	U	Pumping test, 115 gpm, swl 5.6 ft, dd 42.4 ft.
239-854-1	do.	R. Feasley	1959	Drl	59.9	7	a30	Shale	795	9.1	8-15-63	Jet	200	D	Anal.
239-855-1	do.	L. Lardo	1959	Drl	51.8	7	21	do.	780	11.5	8-15-63	Sw	200	D	Anal; yield 4 gpm.
240-819-1	Wyoming	Town of Java	--	Drl	r253	12, 6	--	Shale; sand and gravel?	1,700	Flow	--	Tur	1,000	U	Anal; flow 0.8 gpm, 2.7 ft below LS; temp 48.3, 7-23-63.
-2	do.	do.	--	Dug	4	--	--	Sand and gravel	1,710	Flow	--	--	20,000	--	Anal; infiltration gallery; two 5-inch diameter pipes from galleries to 2 ft X 3 ft X 4 ft-deep collecting basin.
240-823-1	do.	W. Mingle	a1900	Drl	57.2	4 1/2	a30	Shale	1,510	p42.2	7-17-63	Jet	900	F	Anal.
240-826-1	do.	J. Ferington	1960	Drl	107	6	a40	do.	1,080	21.5	7-17-63	Jet	100	D	Anal; iron; yield about 1 gpm.
240-843-1	Erie	F. Riedy	1960	Drl	64.3	6	a29	do.	1,550	1.6	5- 4-64	--	--	A	OW.
240-845-1	do.	N. Schunk	a1890	Dug	11.5	48	--	Sand and gravel	860	8.0	8-22-63	Sw	200	D	Anal.
240-847-1	do.	C. E. Zimmerman, Inc.	1963	Drl	96.3	8	--	Shale	1,065	23.6	4-23-64	Jet	--	D	Gas; wells 240-847-1, -2, -3 are connected to the same pump; combined daily pumpage is 400 gpd.
-2	do.	do.	--	Drl	62.8	8	--	do.	1,065	23.6	4-23-64	Jet	--	D	Do.
-3	do.	do.	--	Drl	87.5	8	--	do.	1,065	p24.5	4-23-64	Jet	--	D	Do.
-4	do.	E. Shero	a1957	Drl	45.6	8	a7	do.	1,190	8.0	4-28-64	--	--	A	OW.
-5	do.	do.	--	Dug	16.2	40	--	Till	1,190	3.5	4-28-64	--	--	A	OW.
240-851-1	do.	J. Cocina	1957	Drl	54.6	10	a35	Shale	850	10.9	8-16-63	Jet	350	D	Water is reported to be salty at times.
240-852-1	do.	E. Schreiner	1956	Dug	24.9	100	24.9	Till	840	15.2	3- 5-63	Sw	350	D	Anal.
241-826-1	Wyoming	G. Reisdorf	1956	Drl	236	6	--	Sand and gravel	1,065	7.2	7-17-63	Jet	400	D	Do.
241-841-1	Erie	D. Colby	1953	Drl	33.2	6	34	do.	980	12.0	8-12-64	Sw	200	D	Iron; yield 5 gpm (r).

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year com- ple- ted	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
241-841-2	Erie	D. Cowles	1963	Drl	r44	6	--	Shale	975	r6	11-63	Sub	150	D	Anal; iron; H_2S.
241-844-1	do.	M. Keller	--	Drl	55.8	8	m10	do.	1,270	5.0	4-23-64	Jet	--	U	Anal.
-2	do.	do.	--	Dug	15.4	40	--	Till	1,270	3.8	4-23-64	Sw	--	D	
241-846-1	do.	W. Beckwith	1959	Drv	r18.5	1 1/4	--	Sand and gravel	850	r11	8-21-63	Sw	--	Ir	Anal; iron; temp 51.3; screened drive point.
-2	do.	I. Gomez	--	Drl	65.8	6	--	do.	840	1.4	4-23-64	--	--	U	
241-847-1	do.	W. Blessing	1955	Dug	15.9	24	--	do.	830	11.0	8-21-63	Sw	100	D	Anal; 12 ft of clay overlies sand and gravel (r).
241-851-1	do.	T. Carlin	1961	Drl	41.9	6	--	Shale	810	9.2	8-16-63	Jet	150	D	Iron; H_2S.
241-854-1	do.	G. Rehg	1959	Drl	36.0	10	m6	do.	770	18.7	8-15-63	Sw	100	D	Anal; gas; yield 3 gpm; an explosive charge was fired at the bottom of the well, the yield was not altered significantly.
241-855-1	do.	H. Shanks	1956	Drl	22.0	6	20	do.	725	15.2	8-15-63	Sw	250	D	Gas; H_2S; temp 55.4; yield 5 gpm (r).
242-827-1	Wyoming	J. Smithley	1957	Drl	143.4	6	--	Gravel	1,035	16.8	8-19-63	Sw	250	D	Anal; iron; gas.
242-834-1	Erie	R. Underhill	1958	Drl	78.4	6	--	do.	940	51.0	8-14-63	Jet	150	D	Anal; iron; gas; H_2S; yield 5 gpm (r).
242-843-1	do.	J. Practico	1955	Drl	58.6	6	52	Shale	1,240	p38.5	7-25-63	Jet	250	D	Anal; gas; H_2S; pumped for 3-day periods alternately with well 242-843-2.
-2	do.	do.	1956	Drl	59.5	6	52	do.	1,240	28.3	7-25-63	Jet	250	D	Pumped for 3-day periods alternately with well 242-843-1.
242-846-1	do.	B. Fletcher	1960	Drl	r60	6	--	Sand and gravel	830	19.5	7-24-63	Jet	100	D	Anal; iron; H_2S; yield 2-3 gpm (r).
242-847-1	do.	N. Biehler	--	Drl	r134	7	--	do.	825	p44.0	8-29-63	Tur	3,000	PS	Anal; iron; temp 51.8; yield 60 gpm (r); open-end casing.
-2	do.	do.	1955	Drl	r149	6	115	do.	820	21.5	8-29-63	--	--	A	Iron; OW; screen 108-115 ft; yield 15 gpm (r).
242-848-1	do.	B. Ott	a1890	Dug	13.2	260	--	do.	790	2.3	4-25-63	--	--	A, PS	Temp 47.5; partly filled with trash; original depth is unknown.
-3	do.	do.	--	Drl	73	10	a36	Shale	790	.40	4-25-63	--	--	A, PS	Temp 47.0.
-4	do.	do.	1953	Drl	41.6	10	37	Sand and gravel	790	1.2	4-27-64	--	--	T	Gas; screen 33.5-37 ft; yield 450 gpm.
-5	do.	do.	1953	Drl	r60	8	41	do.	790	2.1	4-27-64	--	--	T	Gas; casing slotted 37-42 ft; low yield.
-6	do.	N. Biehler	--	Drl	r148	10	141	do.	825	41.6	10-24-63	Tur	--	PS	Screen, 10-inch diameter 100-slot, 136-141 ft; temp 49.2, 10-25-63; supplements withdrawal from well 242-847-1.
242-852-1	Erie	M. Karstedt	1957	Drl	40.1	8	--	Shale	775	20.8	7-22-63	Jet	100	D	Anal; iron; H_2S.
-2	do.	do.	1948	Drl	42.4	6	--	do.	775	21.4	7-22-63	Jet	--	Ir	Anal; iron; H_2S; used only to water lawn.
242-854-1	do.	M. Weaver	1955	Drl	30.4	6	a5	do.	750	3.2	7-22-63	Sw	100	D	Anal; iron; H_2S; yield 10 gpm (r).
243-814-1	Wyoming	W. Hulme	1941	Drl	63.4	6	--	do.	1,970	9.2	8-12-63	Sw	500	D	Anal; iron; gas.
243-827-1	Erie	N. Metzger	1962	Drl	177	6	--	Sand and gravel	1,000	15.9	7-18-63	Sw	200	D	Anal; H_2S.
243-828-1	do.	L. Hudson	1956	Drl	r62	6	59	do.	990	r15	--	Jet	1,100	F	Anal; H_2S.
243-835-1	do.	F. Shilling	1949	Drl	41.3	6	--	do.	905	6.5	8-14-63	Sw	250	D	Anal; iron.
243-847-1	do.	R. Holtz	1962	Drl	61.5	6	18	Shale	845	p39.6	7-23-63	Jet	150	D	Anal; iron; yield 3-4 gpm (r).
243-848-1	do.	A. Parker	1957	Drl	62.0	6	a34	do.	835	39.4	7-27-63	Jet	100	D	Anal; iron.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
243-849-1	Erie	C. Lockwood	1964	Drl	--	6	a24	Shale	810	--	--	--	--	ir	Yield 25 gpm (r); casing 27 ft in depth and is slotted to admit water from a zone of fractured shale.
243-853-1	do.	R. Filler	1954	Drl	51.7	6	2	do.	760	24.7	7-22-63	Jet	100	D	Anal; iron; yield 10 gpm (r).
243-854-1	do.	Acma Shale Brick Co., inc.	1926	Drl	28.2	108	7	do.	660	19.3	7-22-63	Sw	--	U, i	Anal; temp 49.5.
243-855-1	do.	do.	1956	Drl	r50	6	--	do.	655	r18	--	Sw	--	i	Anal; temp 51.5, 7-22-63.
244-814-1	Wyoming	K. Lee	1953	Drl	r150	6	a120	do.	1,695	37.1	8-10-63	Jet	300	D	Iron.
244-824-1	do.	R. Daniel	1958	Drl	28.3	6	26	do.	1,615	6.7	7-20-63	Sw	150	D	Anal; iron; H_2S; yield 10 gpm (r).
244-826-1	do.	A. Almeter	1956	Dug	13.3	30	--	Sand and gravel	1,270	6.3	7-20-63	Sw	250	D	Anal; 12 ft of clay overlies sand and gravel (r).
244-829-1	Erie	J. McLaughlin	1960	Drl	r147.5	6	--	do.	930	r15	7-62	Jet	500	D	Anal; gas.
244-830-1	do.	K. Ulrich	1960	Drl	46.5	8	8	Shale	1,110	10.5	7-18-63	Jet	150	D	Anal; yield 15 gpm (r).
244-835-1	do.	R. Plugh	1958	Drl	92.8	6	--	Sand and gravel	895	11.4	8-14-63	Jet	150	D	Anal; iron; gas.
244-836-1	do.	D. Heitman	1956	Drl	r128	7	a60	Shale	895	27.4	8-14-63	Jet	300	D	Anal; iron; gas; yield 13 gpm (r).
244-844-1	do.	R. Baun	1955	Drl	50.5	6	a20	do.	900	13.1	7-25-63	Jet	250	D	Anal; iron; yield 2 gpm (r).
244-846-1	do.	K. Bieger	1957	Drl	65.3	6	15	do.	875	6.4	7-23-63	Jet	450	D	Anal; iron.
244-848-1	do.	F. Martino	1959	Drl	65.1	6	18	do.	725	4.6	7-22-63	Jet	--	U, D	Anal; H_2S.
245-817-1	Wyoming	R. Schwedt	1956	Drl	43.9	6	--	do.	1,410	17.8	8-10-63	Sw	200	D	Anal; yield 6 gpm (r).
245-818-1	do.	Varysburg Water District	1947	Drl	r118	6	--	Sand and gravel	1,125	6	2-12-63	Tur	20,000	PS	Anal; temp 50, 7-26-63; open-end casing; test pumped at 125 gpm; pumping test 60 gpm, dd 6 ft (r).
245-830-1	Erie	R. Wilson	1963	Drl	r43	8	a40	Sand and gravel; shale	950	30.7	7-18-63	Sub	200	D	Anal; bailed 20-25 gpm (r).
245-846-1	do.	G. Calaiacovo	1960	Drl	57.7	6	a45	Shale	785	8.3	7-25-63	Jet	250	D	Anal; iron; yield 3 gpm (r).
246-818-1	Wyoming	G. Zwetsch	1941	Drl	132	6	a110	do.	1,090	Flow	--	--	100	D	Anal; iron; flowed 20 gpm, 15 ft above LS when drilled (r); no pump; two-story house is supplied by artesian pressure.
246-824-1	do.	C. George	1949	Drl	24.1	6	a16	do.	1,525	6.7	8-10-63	Sw	100	D	Anal; yield 2 gpm (r).
246-830-1	Erie	C. Reed	1960	Drl	76	12	a45	do.	1,150	p22.9	8- 2-63	Jet	300	D	Anal; gas; yield 2 gpm (r); a dynamite charge was fired in the well in an unsuccessful attempt to improve the yield; a well drilled 80 ft away, 50 ft deep is "dry."
246-833-1	do.	O. Peterson	1962	Drl	r140	6	75	Shale	1,015	p68.5	8- 1-63	Jet	100	D	Anal; iron; gas; yield 2 gpm.
246-836-1	do.	Village of East Aurora	1934	Drl	r105	12	--	Sand and gravel	895	r9.5	10-14-43	Tur	250,000	PS	Iron; screen, 12-inch diameter, 6-gage slot, 75-105 ft; gravel packed; pumping rate 500 gpm; pumping test 690 gpm, swl 9.5 ft, dd 46.5 ft (r).
-2	do.	do.	1941	Drl	r130.5	16	--	do.	895	r5	1-13-42	Tur	260,000	PS	Iron; screen, 16-inch diameter, 6-gage slot, 120.5-130.5 ft; gravel packed; pumping rate 430 gpm; pumping test 700 gpm, swl 5 ft, dd 102 ft.
-3	do.	do.	1950	Drl	r123	12	--	do.	895	r13	10-11-51	Tur	--	U, PS	Screen, 18-inch diameter, 107.5-122.5 ft; gravel packed; pumping test 420 gpm, swl 13 ft, dd 16.4 ft.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
246-836-4	Erie	Village of East Aurora	1961	Drl	r122	12	--	Sand and gravel	895	r7	5-16-61	Tur	250,000	PS	Iron; screen, 12-inch diameter, 6-gage slot, 107-122 ft; gravel packed; pumping rate 490 gpm.
246-843-1	do.	L. Godfrey	1950	Drl	45.3	6	a40	do.	830	17.9	7-26-63	Jet	100	D	H_2S; gas; clay overlies water-bearing gravel (r).
246-848-1	do.	C. Stocking	1953	Drl	27.8	6	a7	Shale	715	5.3	7-27-63	Jet	--	Ir	H_2S; used for lawn sprinkling only.
246-849-1	do.	G. Bapst	1955	Drl	39.1	7	a5	do.	685	9.2	7-27-63	Jet	250	D	Anal.
247-823-1	Wyoming	P. Heeter	1957	Drl	36.6	6	--	Sand and gravel	1,160	15.6	8- 9-63	Jet	300	D	Do.
247-833-1	Erie	T. Siclari	1958	Drl	28.0	6	a16	Shale	945	6.5	8- 1-63	Sw	--	U	Iron; H_2S; unused because water quality is poor.
247-836-1	do.	A. Schuster	1961	Drl	46.1	6	a30	do.	860	15.8	7-30-63	Sw	250	D	Iron; H_2S; yield 10 gpm (r).
247-838-1	do.	D. Engel	1956	Drl	33.4	6	a12	do.	960	6.6	7-30-63	Sw	150	D	Anal; H_2S.
247-840-1	do.	A. Malovich	1959	Drl	40.4	8	a30	do.	890	21.1	7-26-63	Sw	200	D	Anal; Iron; blasting charge fired in well to improve yield.
247-842-1	do.	J. Smith	1959	Drl	51.5	7	--	Sand	830	9.4	7-26-63	Jet	250	D	Anal; Iron; H_2S.
248-818-1	Wyoming	O. Block	a1940	Drl	r140	6	--	Shale	1,045	Flow	--	Sw	1,400	D	Anal; gas; Iron; temp 51.2, 8-12-63; flows about 1 gpm, 2.6 ft below LS; occasionally water level has fallen below end of drop pipe, 25 ft below surface while pumping.
248-825-1	do.	N. Fox	1963	Drl	r112	8	12	do.	1,115	28.8	8- 2-63	Sub	150	D	Anal; yield 1 gpm (r); water-bearing zone at 34 ft; no lower water-bearing zones.
248-828-1	do.	W. Deazley	1957	Drl	r112	8	8	do.	1,210	20.3	8- 2-63	Jet	300	D	Anal; yield 1 gpm (r); water-bearing zone at 30 ft; attempted to increase yield by blasting at three different depths; occasionally is pumped dry.
248-829-1	Erie	O. Whitman	1958	Drl	36.4	6	a28	do.	1,150	12.5	8- 2-63	Jet	50	D	Anal; H_2S; yield 2.5 gpm (r).
248-833-1	do.	R. Gilbert	1957	Drl	35.9	6	33	Sand and gravel; shale	970	11.4	8- 1-63	Sw	400	D	Anal; Iron; H_2S.
248-838-1	do.	H. Gaczewski	1954	Drl	58.9	6	2	Shale	925	21.5	7-30-63	Jet	500	D	Anal; gas.
248-839-1	do.	Moog Servocontrols, Inc.	1957	Drl	85.7	8	--	do.	905	p40.4	9-23-63	Sub	--	I	Anal; H_2S.
-2	do.	do.	1957	Drl	24.7	12	--	do.	905	p14.4	9-23-63	Sub	--	I	Do.
-3	do.	do.	1958	Drl	76.8	10	--	do.	910	p26.9	9-23-63	Sub	--	I	H_2S.
-4	do.	do.	1962	Drl	r225	18	a10	do.	910	--	--	--	--	T	Yield 10 gpm (r).
248-841-1	do.	R. Struck	1960	Drl	43.8	6	a40	do.	770	17.9	7-26-63	Sw	200	D	Anal; Iron; H_2S; gas; yield 3 gpm (r).
248-844-1	do.	O. Eaton	1959	Drl	19.7	6	a15	do.	740	8.5	7-26-63	Sw	250	D	Anal; H_2S; yield 5 gpm (r); blasting charge was fired in well to increase yield.
248-850-1	do.	Spring Perch Co., Inc.	1936	Drl	r40	5	--	do.	580	p21.0	3-20-63	Jet	10,000	I	Anal; H_2S; yield 29 gpm; another similar well is also in use.
249-809-1	Wyoming	H. Meeder	--	Dug	13.8	24	--	Sand and gravel	1,205	9.1	6- 9-64	Sw	150	D	
249-810-1	do.	C. Bailey	1963	Drl	54.4	6	--	do.	1,190	21.6	6-10-64	Jet	100	D	
-2	do.	W. Dersam	--	Dug	10.5	36	--	Till	1,180	4.6	6-10-64	Sw	--	A	
249-818-1	do.	G. Knobloch	--	Drl	58.6	4	a10	Shale	1,075	23.5	8-12-63	Jet	100	D	Anal; yield 3 gpm (est).
249-823-1	do.	L. Green	1963	Drl	81.5	8	19	do.	1,260	13.3	8- 9-63	Jet	400	D	Anal; yield 1.5 gpm (r).

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
249-826-1	Wyoming	G. Hoffman	1953	Drl	r70	6	a30	Shale	980	r20	7-62	Jet	200	D	Anal; iron; H_2S; yield 2 gpm (r); water may enter at bottom of casing.
249-833-1	Erie	W. Rider	1961	Drl	67.8	6	51	do.	900	15.4	8- 1-63	Jet	200	D	Anal; iron; H_2S; yield 5 gpm (r).
249-836-1	do.	D. Domon	1960	Drl	70.9	10	--	do.	920	19.2	7-31-63	Jet	200	D	Anal; iron; used only during summer.
-2	do.	do.	1955	Dug	21.3	36	8	do.	920	9.3	7-31-63	Sw	200	D	Anal; iron; H_2S; this well goes dry in summer and well 249-836-1 is used in its stead.
249-840-1	do.	W. Kaufman	1961	Drl	22.1	6	--	Sand	830	10.5	7-26-63	Sw	250	D	Anal; iron; H_2S.
250-810-1	Wyoming	R. Dusing	--	Drl	62	6	--	Shale	1,170	14.4	6- 9-64	Jet	250	F	Anal; H_2S.
-2	do.	G. Dersam	--	Drl	r40	6	--	Sand and gravel	1,145	p2.5	6- 9-64	Sw	400	F	Well was partly filled with fine gravel to 33.7 ft to make water clear of suspended particles.
-3	do.	C. Pflaum	--	Dug	15.5	24	--	do.	1,170	12.3	6-10-64	Sw	100	D	
250-816-1	do.	E. Marley	--	Dug	6.1	30	--	do.	1,010	4.5	8- 5-64	Sw	150	D	Anal.
250-817-1	do.	T. Spink	1960	Drl	r195	6	--	do.	1,005	r5	--	Sub	1,250	F	Anal; iron; H_2S; yield 40 gpm (r).
250-821-1	do.	New York State Natural Gas Co.	1964	Drl	--	10	a35	Lockport Dolomite	1,390	--	8-10-64	--	--	GT	Anal; "black" water obtained at 1,808 ft; top of Lockport Dolomite 1,800 ft, bottom 1,917 ft; fresh water obtained at 80 ft in insufficient quantity for drilling.
250-824-1	do.	W. Wendler	a1920	Dug	12.1	30	--	Sand and gravel	1,140	8.0	8- 8-63	Sw	20	D	Anal; iron; H_2S.
250-827-1	do.	S. Zielonka	1961	Dug	9.2	18	--	do.	940	6.2	8- 8-63	Sw	100	D	
250-832-1	Erie	T. Swing	1962	Drl	25.4	6	--	do.	870	4.5	6- 8-64	Sw	100	D	
250-835-1	do.	J. Kipfer	1960	Drl	50.7	6	a20	Shale	845	16.4	7-30-63	Jet	100	D	Anal; iron; yield 4 gpm (r).
-2	do.	F. Litwiller	1959	Drl	61.4	6	a20	do.	845	17.2	7-30-63	Jet	300	D	Iron.
-3	do.	Holmwood Builders	1964	Drl	60.1	6	--	Sand?	840	10.0	7- 8-64	--	--	D	
251-809-1	Wyoming	W. Spring	--	Drl	122.7	6	a60	Shale	1,160	p52.4	6-10-64	--	--	A	Water level affected by pumping well 69 ft to northeast; OW.
-2	do.	H. Ewell	1961	Drl	64.8	6	--	do.	1,135	15.1	6-11-64	Jet	200	D	Anal; iron; a destroyed well on same property was 40 ft deep, finished in sand.
251-815-1	do.	M. Dau	1937	Drl	130	6	130	Sand and gravel	1,010	49.7	6-18-64	Jet	100	D	Anal.
251-829-1	Erie	R. Caplick	1959	Drl	57.8	6	47	Shale	950	15.6	8- 1-63	Jet	400	D	Anal; iron; H_2S; yield 5 gpm (r).
251-832-1	do.	R. Toepfer	1957	Drl	57.3	6	6	do.	920	5.5	7-31-63	Sw	350	D	Anal; iron; H_2S.
-2	do.	R. Polcyn	--	Drl	77.5	6	--	do.	930	13.1	6- 8-64	Sw	--	A	H_2S; salty water; yield 5-6 gallons per hour (r).
-3	do.	do.	--	Dug	24	24, 1	20.3	Till; shale	930	9.5	6- 8-64	Sw	100	D	Goes dry in late summer; dug to bedrock; when well was dry, a 1-inch diameter hole was drilled into bedrock from 20.3-24 ft and obtained a small quantity of water.
-4	do.	G. Dabb	1964	Drl	61.3	10	--	Shale	895	9.1	6- 8-64	--	--	U	Bailed 4 gpm (r).
251-834-1	do.	P. Schulz	1961	Drl	84.0	6	--	do.	830	4.7	7-31-63	Jet	250	D	Anal; iron; H_2S; gas.
-2	do.	M. McGowan	--	Drl	47.5	6	--	Sand and gravel	830	6.5	6- 8-64	--	--	A	OW.
251-837-1	do.	E. Zabrocki	1958	Drl	73.8	6	50	Shale	780	22.5	7-30-63	Jet	200	D	Anal; water-bearing zones at 50 ft and 65 ft.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
251-850-1	Erie	Donner-Hanna Coke Corp.	1928	Drl	r119	6	--	Limestone	585	--	--	AL	35,000	I	H_2S; yield 30 gpm (r); in use about 150 days per year during summer and early fall; a test boring nearby penetrated 62.5 ft of silty clay, refusal at 62.5 ft.
-2	do.	do.	1928	Drl	r116	6	--	do.	585	--	--	AL	35,000	I	Anal; also see remarks for well 251-850-1.
252-814-1	Genesee	A. Waite	1963	Drl	99	6	--	Sand and gravel	1,125	p46.3	6-18-64	Jet	500	F	Bailed 5 gpm (r).
252-815-1	do.	F. Stevens	1963	Drl	88	5 5/8	80	Shale	975	23.8	6-18-64	Jet	--	D	
252-818-1	do.	E. Snyder	1959	Drl	r23.5	6	a19	do.	1,040	r8	--	Sw	200	D	Anal; iron; H_2S; yield 5 gpm (r).
252-850-1	Erie	Artic Ice Co.	a1900	Drl	r180	6	a20	Limestone; Camillus Shale	590	r20	1951	Tur	--	U	Anal; yield 300 gpm (r); supplied 300,000 gpd.
252-852-1	do.	New York Telephone Co.	1955	Drl	r80	12	53	Limestone	605	30	3-20-63	Tur	--	U	H_2S; pumping test 85 gpm, swl 28 ft, dd 7 ft after 34 hours of pumping.
-2	do.	W & F Manufacturing Co.	1947	Drl	r101	8	8	do.	590	r,p37	1951	Tur	--	I	H_2S; water-bearing zones from 89 to 101 ft depth, underlying cherty beds in Onondaga Limestone; pumping data, 30 gpm, dd 17 ft (r).
-3	do.	Fairmont Foods Co., Inc.	1925	Drl	r127	8	30	do.	580	rFlow	1951	Tur	40,000	I	Anal; H_2S.
253-813-1	Genesee	D. Lapp	--	Drl	65.3	6	--	Sand and gravel	990	14.1	6-12-64	Jet	250	D	
253-820-1	do.	F. Pieri	1963	Drl	63.7	6	--	do.	1,060	19.3	7-30-64	Sw	250	D	
253-824-1	do.	A. Baginski	1960	Drl	41.1	6	--	do.	995	5.7	8- 8-63	Jet	150	D	Anal; yield 3 gpm (r).
253-829-1	Erie	J. Murray	1961	Drl	26.1	8	--	Shale	900	p11.3	7-31-63	Sw	250	D	Anal; iron; water level occasionally is pumped down to bottom of suction pipe at 24 ft.
-2	do.	do.	1961	Drl	22.0	6	--	do.	900	9.18	7-31-63	Sw	--	U	Iron.
-3	do.	Village of Alden	1961	Drl	r27	60, 18	27	Sand and gravel	840	--	--	Tur	75,000	PS	Concrete tile from 0-16 ft installed 1947; 18-inch diameter screen, gravel packed, from 16-27 ft installed 1961.
253-832-1	do.	D. Klinkman	1957	Drl	47.8	6	a40	Shale	830	11.3	7-31-63	Jet	250	D	Anal; iron; yield 10 gpm (r).
253-834-1	do.	J. Gilbride	1962	Drl	61.7	6	--	do.	775	28.8	7-31-63	Jet	250	D	Anal; iron; H_2S; yield 10 gpm (r).
253-840-1	do.	D. Klock	--	Drl	24.3	5	m8	do.	660	9.3	6-27-63	Sw	--	U	Anal; temp 49.
253-850-1	do.	Rivoli Theater	1941	Drl	r110	8	20	Limestone	605	r,p40	1951	Tur	50,000	C	Air-conditioning use; water is returned to ground through a disposal well 150 ft away; pumping data, 150 gpm, dd 4 ft (r).
-2	do.	Roosevelt Theater	1936	Drl	r60	8	20	do.	605	r,p30	1951	Tur	60,000	C	H_2S; air-conditioning use; water is returned to ground through a disposal well 150 ft away.
254-812-1	Genesee	E. Rhodes	1959	Drl	33.3	6	--	Sand and gravel	985	13.0	6-16-64	Jet	1,250	F	Iron; yield 15 gpm (r).
254-826-1	do.	F. Kaczmerek	1950	Drl	67.5	6	a50	Shale	940	11.8	8- 9-63	Jet	1,250	F	Anal; iron; H_2S; yield 8 gpm (r).
254-829-1	Erie	Village of Alden	1957	Drl	r35.7	16, 8	34	Sand and gravel	830	r7.1	1-31-58	Tur	100,000	PS	Iron; H_2S; screen, 8-inch diameter, 125-slot from 29-34 ft; gravel packed from 22-34 ft; pumping test, 220 gpm, swl 8.6 ft, dd 11.1 ft after 8 hours pumping.
-2	do.	do.	--	Dug	r14	140	--	do.	825	--	--	Sw	9,000	PS	One of a group of three dug wells at Alden No. 1 pumping plant; total pumpage from these three wells is about 27,000 gpd.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
254-829-3	Erie	Village of Alden	1964	Drl	ra35	--	--	Sand and gravel	845	--	--	Tur	--	PS	Construction of well is reported to be similar to that of well 254-829-1; yield 220 gpm.
254-830-1	do.	W. and J. Fahringer	a1904	Drl	r1,150	8	--	Lockport Dolomite?	840	r350	8-62	Dw	--	C	Gas test well which yields a black brine used for mineral baths.
254-834-1	do.	G. Glose	1962	Drl	66.2	10	a7	Shale	770	p26.3	8-19-64	Jet	450	D	H_2S.
-2	do.	R. Maue	1961	Drl	52.9	6	a10	do.	765	7.1	8-19-64	Jet	200	D	Iron; H_2S; water-bearing zone at 25 feet; blasting charge fired at 20-25 ft to increase yield.
255-812-1	Genesee	Western New York Concrete Corp.	1957	Drl	85.9	8	--	Sand and gravel	965	2.4	7-17-63	--	--	A	Anal; screen, 8-inch diameter; 77.9-85.9 ft; pumping test 60 gpm, swl 2 ft, dd 42 ft (r).
-2	do.	do.	1957	Drl	81.4	8	--	do.	970	7.3	7-17-63	--	--	A	Yield about 50 gpm (r); OW.
-3	do.	H. Eart	1944	Drl	38.5	6	--	do.	945	6.3	6-16-64	Sw	1,000	F	Iron.
255-848-1	Erie	Commodore Theater	--	Drl	r75	8	7	Limestone	640	0	1951	Tur	--	C	Air-conditioning use; pumping data, 130 gpm, dd 10 ft (r).
255-850-1	do.	Nagel Dairy	--	Drl	r90	8	20	do.	660	r,p20	1951	Tur	--	C	Pumping data, 180 gpm, dd 45 ft.
256-818-1	Genesee	D. Hegge	1959	Drl	45	6	a30	Shale	935	9.7	7-30-64	Jet	700	F	Yield 8 gpm (r).
256-822-1	do.	K. Skeet	1962	Drl	27.5	6	3	do.	890	7.3	7-30-64	Sw	300	D	Anal; H_2S.
256-831-1	Erie	Sieracki	1959	Drl	52.3	6	a40	do.	800	16.6	8-19-64	Jet	200	D	Anal.
256-835-1	do.	Huber	1964	Drl	68.5	6	--	do.	770	18.7	7-23-64	--	--	D	
-2	do.	C. Suess	1958	Drl	59	6	a34	Limestone	750	29.6	8-19-64	Jet	250	D	Anal.
256-844-1	do.	Twin Industries Corp., Aerospace Division	1951	Drl	r117	6	--	do.	715	--	--	Tur	--	U, I	Iron; H_2S; well is unused because quality of water has deteriorated; formerly supplied 150,000 gpd; yield about 285 gpm.
-2	do.	do.	1951	Drl	90	8	--	do.	715	r45	7- 3-64	--	--	U, I	
257-812-1	Genesee	E. Foster	1955	Drl	65	6	--	Sand and gravel	895	5.2	6-16-64	Jet	1,500	F	
-2	do.	W. Cook	1960	Drl	71.3	6	--	do.	895	5.2	6-16-64	Sw	150	D	Anal; iron.
257-817-1	do.	J. Penkszyck	1961	Drl	r52	--	--	Shale	920	--	--	Jet	--	D	Iron.
257-824-1	do.	Village of Corfu	1954	Drl	r39.3	12, 8	30	Sand and gravel; shale	850	6	1- 6-54	Tur	55,000	PS	Temp 49.8, 1-17-63; screen, 8-inch diameter, 100-slot from 34.3-39.3 ft; 12-inch diameter gravel pack from 32-39.3 ft; pumping rate 90 gpm; pumping test 100 gpm, swl 6 ft, dd 11 ft.
-2	do.	do.	1952	Drl	r36.6	12	32	do.	850	4	10-27-52	--	--	A	Pumping test, 110 gpm, swl 4 ft, dd 12 ft.
257-855-1	Erie	E. I. du Pont de Nemours & Co.	1925	Drl	r101	8	55	Camillus Shale	590	r30	1951	AL	--	A, I	Yield 125 gpm; 1 of 3 wells of the "north" well field; combined pumpage was 200,000 gpd.
-2	do.	do.	1925	Drl	r123	8	55	do.	590	r30	1951	AL	--	A, I	Yield 125 gpm; 1 of 7 wells of the "south" well field; combined pumpage was 1 mgd.
258-809-1	Genesee	O-AT-KA Milk Products Cooperative, Inc.	1958	Drl	r49.2	18, 10	--	Sand and gravel	900	26.5	8- 1-58	Tur	--	I	Screen, 10-inch diameter, 125-slot, from 41 to 49 ft; gravel packed, Cape May No. 5 gravel; pumping test, 456 gpm, swl 26.5 ft, dd 12.8 ft.
-2	do.	do.	1958	Drl	--	8	--	do.	900	22.2	5- 8-63	Tur	--	I	
258-813-1	do.	H. Loveland	--	Drl	11.7	3	--	Shale	900	8.1	6-26-63	--	--	A	
-2	do.	do.	--	Drl	33	6	--	do.	900	12.1	6-26-63	Sw	--	U	Anal; iron; temp 48.0.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
258-815-1	Genesee	F. Peck	--	Drl	31	6	--	Shale	920	8.1	6-26-63	Sw	50	D	Anal; iron; temp 49.0; yield 12 gpm (r).
258-822-1	do.	E. Lewis	1964	Drl	41.6	6	41.6	Sand	870	9.1	8-19-64	Sw	400	Ag	Anal; H_2S; yield 11 gpm (r).
258-827-1	do.	E. Powenski	1952	Drl	36.5	6	a34	Limestone	835	31.3	8-19-64	Jet	250	D	H_2S; yield 7 gpm (r).
258-833-1	Erie	B. Fields	1960	Drl	62.6	6	a13	do.	775	p22.7	8-18-64	Sub	300	D	Anal.
258-837-1	do.	R. Bowman	1956	Drl	76.2	6	a22	do.	740	19.4	8-18-64	Jet	300	D	Do.
258-843-1	do.	W. Voss	--	Drl	62	8	--	Camillus Shale	615	Flow	--	--	5,000	A	Anal; H_2S; temp 50.8, 8-14-64; flows about 5 gpm at LS.
258-853-1	do.	Linde Div., Union Carbide Corp.	1944	Drl	r375	8	87	Camillus Shale and Lockport Dolomite	600	r,p115	1944	Tur	--	U	H_2S; drilled to 130-ft depth in 1943 and deepened in 1944; "black" water entering from Lockport Dolomite after deepening made well unusable; yield 3,000 gpm (r); pumping test, 1,090 gpm, dd 53 ft.
-2	do.	do.	1944	Drl	r375	8	86	do.	600	r,p82	1944	Tur	--	U	H_2S; drilled to 157-ft depth in 1943 and deepened in 1944; water obtained at 90 ft from a gypsiferous zone in Camillus Shale and "black" water at 312 ft from the Lockport Dolomite which was first penetrated at 288 ft; yield from upper water-bearing zone 90 gpm, dd 22 ft; lower zone was not tested.
258-855-1	do.	Dunlop Tire & Rubber Co.	1943	Drl	r137	12	69	Camillus Shale	590	p36	10-27-52	Tur	--	I	H_2S; pumping rate 1,000 gpm (r); pumping test 500 gpm, swl 36 ft, dd 17 ft; this well and well 258-855-2 yield a combined total of 600,000 gpd.
-2	do.	do.	1943	Drl	r139.7	--	71	do.	590	p54.3	7-16-64	Tur	--	I	H_2S; pumping rate about 1,000 gpm (r); pumping test 1,000 gpm, swl 36 ft, dd 26 ft; this well and well 258-855-1 yield a combined total of 600,000 gpd.
-3	do.	do.	1952	Drl	r120	--	--	do.	592	p39	10-27-52	Tur	--	I	H_2S; pumping test 1,500 gpm, swl 39 ft, dd 38 ft.
259-809-1	Genesee	O-AT-KA Milk Products Cooperative, Inc.	1963	Drl	r60	20, 16	--	Sand and gravel	890	r15	4-27-62	Tur	1,000,000	I	Anal; screen, 13 1/8-inch diameter, 10 ft of 60-slot, 10 ft of 125-slot, from 40-60 ft; pumping rate about 1,200 gpm (r); pumping test 600 gpm, swl 15 ft, dd 1.5 ft (r).
-2	do.	City of Batavia	1963	Drl	r69	16	--	do.	890	14.0	5- 8-63	Tur	--	PS	Anal; H_2S; screen, 16-inch telescope, 125-slot, 52.9-69 ft; pumping rate 1,000 gpm.
-3	do.	do.	1962	Drl	54.1	8	--	do.	890	11.7	5- 6-63	--	--	T	Depth 61 ft (r); screen, 6-inch diameter, 100-slot, from 51-61 ft; pumping test 235 gpm, swl 18.3 ft, dd 0.5 ft (r); OW.
-4	do.	O-AT-KA Milk Products Cooperative, Inc.	1963	Drl	52.2	8	--	do.	890	p13.0	5- 7-63	--	--	T	
-5	do.	City of Batavia	1962	Drl	60.2	8	--	do.	890	13.7	5- 8-63	--	400,000	T	Depth 70 ft (r); screen, 6-inch diameter, 100-slot, from 60-70 ft; pumping test (r), 235-259 gpm, swl 18.5 ft, dd 0.5 ft after 24 hours discharge.
-6	do.	do.	1963	Drl	r75	16	--	do.	895	r14.2	5-27-63	Tur	--	PS	Screen, 16-inch diameter; test pumped at 1,000 gpm.
-7	do.	do.	1963	Drl	r60	8	--	do.	890	r13.7	2-15-62	--	400,000	X, T	H_2S (r); pumping test 200 gpm, swl 13.7 ft, dd 4.4 ft after 24 hours discharge.
259-817-1	do.	D. Beals	1960	Drl	r33	--	--	do.	865	r3	1960	Sw	100	D	Anal; H_2S; yield 4 gpm (r).
259-818-1	do.	Bitterman Bros., Inc.	--	Drl	18.3	12, 6	--	do.	--	6.6	9-17-63	Sw	--	C, D	
259-820-1	do.	A. Winters	1960	Drl	22.6	6	--	Limestone	880	7.4	9-17-63	Sw	500	C, D	
259-822-1	do.	J. Daley	1956	Drl	70	6	--	Sand	900	27.1	8-19-64	Jet	200	D	Anal; H_2S.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
259-823-1	Genesee	R. Reid	a1961	Drl	64.4	6	--	Sand	885	p36.8	9-17-63	Jet	300	D	Anal; Iron; yield 30 gpm (r); cased to about 69 ft (r).
259-824-1	do.	Bell Aircraft Corp.	1957	Drl	r95	12	41.5	Limestone	870	r22	6- 3-57	--	--	T	Pumping test, 100 gpm, swl 22 ft, dd 30 ft.
-2	do.	do.	1957	Drl	r63.5	12	36	do.	870	r19	6-13-57	--	--	T	Pumping test, 100 gpm, swl 19 ft, dd 12 ft.
259-830-1	Erie	B. Wurthman	1964	Drl	32	6	--	Sand	795	11.9	8-18-64	Sw	250	D	Anal.
259-835-1	do.	R. Cummings	1959	Drl	77.1	6	--	Camillus Shale; sand	675	47.1	8-18-64	Jet	--	D	Anal; H_2S; cased to 88 ft (r).
-2	do.	J. Burns	1957	Drl	88.1	6	88	do.	675	45.2	8-18-64	Jet	--	D	Anal.
259-841-1	do.	Community Reformed Church	1955	Drl	51.7	6	a46	Camillus Shale	620	4.8	8-14-64	Jet	--	D	H_2S.
259-846-1	do.	A. Adorjan	1954	Drl	42.6	6	--	do.	595	14.3	8-13-64	Sw	--	D	Iron.
259-847-1	do.	D. Kuss	1954	Drl	30	6	--	do.	595	19.7	8-13-64	Jet	--	U, D	H_2S.
259-857-1	do.	Mesmer & Sons Dairy, Inc.	1953	Drl	r58	6	55	do.	595	r15	--	--	--	A	H_2S; yield 60 gpm (r).
259-900-1	do.	G. Franke	--	Drl	63.6	6	--	do.	590	28.5	7- 9-64	Jet	--	A	H_2S; low yield.
300-814-1	Genesee	W. Cox	1957	Drl	26.4	6	--	Limestone	885	p9.1	6-26-63	Sw	250	D	Anal; H_2S; temp 49.0.
300-815-1	do.	N. Johnson	--	Dug	20.9	32	--	Sand and gravel	900	17.5	9-16-63	Sw	400	D	Anal.
-2	do.	Alden Farms Co.	1962	Drl	33.7	6	--	Limestone	900	21.7	9-16-63	Sw	100	D	Do.
300-817-1	do.	W. McMullen	1961	Drl	r85	6	--	do.	920	--	--	Sub	400	D	Anal; H_2S.
300-820-1	do.	R. Gross	1956	Drl	r60	--	--	do.	890	--	--	Jet	250	D	Anal; Iron.
300-824-1	do.	Bell Aircraft Corp.	1957	Drl	r100	12	24	do.	860	r33	6-25-57	--	--	T	Pumping test, 104 gpm, swl 33 ft, dd 28 ft.
-2	do.	J. Fuller	1955	Drl	42.3	6	--	Sand	855	12.9	7-23-64	Sw	100	D	Anal.
300-826-1	do.	E. VanAlstine	1952	Drl	53	6	--	Limestone	830	16.3	7-22-64	Jet	50	D	
-2	do.	A. Bettio	1960	Drl	r30	6	--	do.	840	9.1	7-23-64	Sw	200	D	
300-827-1	Erie	L. Weaver	--	Drl	r120	6	--	do.	830	45	7-22-64	Jet	150	D	
300-831-1	do.	A. Drachenberg	1963	Drl	38.5	6	a35	Camillus Shale	675	11.4	8-18-64	Sw	50	D	Anal; Iron; H_2S.
300-833-1	do.	C. Colf	1960	Drl	46.3	6	a35	do.	685	7.6	8-18-64	Jet	200	D	Anal; iron.
300-839-1	do.	H. Thompson	1964	Drl	26	6	--	do.	610	18.1	8-17-64	Sw	--	U	Anal; H_2S.
300-842-1	do.	R. Blatter	--	Drl	41.9	6	--	do.	595	12.4	7-10-64	Sw	200	D	
300-844-1	do.	J. Calahan	1948	Drl	50	6	--	do.	585	2.4	8-14-64	--	--	A	Iron; H_2S.
300-848-1	do.	R. Lewis	1940	Drl	33.7	8, 6	--	do.	585	10.5	8-13-64	Sw	--	Ir	H_2S.
300-859-1	do.	L. Fleishmen	1918	Drl	r55	6	55	do.	590	r14	--	Dw	--	Ag	Iron; H_2S.
-2	do.	--	1952	Drl	53	6	--	do.	595	18.3	7- 9-64	--	--	A	
301-813-1	Genesee	R. and R. Call	1961	Drl	r70	6	3	Limestone	925	--	--	Sub	--	F	Anal; Iron; yield 10-15 gpm (r).
-2	do.	do.	1959	Drl	76.8	6	a5	do.	925	38.0	6-27-63	--	--	A	Iron.
301-822-1	do.	J. Deja	--	Drl	r39	6	--	do.	855	--	--	--	--	F	Anal.
301-823-1	do.	W. Hetrick	1963	Drl	r75	6	a25	do.	850	r29	11-63	Jet	150	D	Yield 8-10 gpm (r).

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
301-833-1	Erie	C. Jones	1964	Drl	23.6	6	a18	Camillus Shale	645	6.6	8-18-64	--	--	U, D	
301-838-1	do.	H. Frey	1959	Drl	40.6	6	a40	do.	630	25.1	8-17-64	Sub	350	D	Anal; iron.
301-848-1	do.	--	1964	Drl	75.3	12	43	do.	575	13.2	10- 2-64	--	--	A, T	Yield 30 gpm; water-bearing zones at top of rock and at 65-70 ft interval.
301-857-1	do.	Grand Island Ready Mix Concrete Corp.	1954	Drl	r60	6	--	do.	595	--	--	Jet	6,000	I	H_2S.
302-821-1	Genesee	W. Phelps	1959	Drl	67.3	6	a5	Limestone	895	25.6	8-20-63	Sw	1,500	F	Anal.
-2	do.	B. Knapp	1956	Drl	r102	6	--	do.	870	46.5	7-15-64	Sub	1,500	F	
302-825-1	do.	C. Moses	1959	Drl	r49	6	--	Camillus Shale	690	r20	--	Sw	50	D	Yield 20 gpm (r).
302-841-1	Erie	H. Moratti	1947	Drl	61.4	6	--	do.	585	10.6	7-10-64	Sw	--	U	
302-842-1	do.	R. Wood	1960	Drl	64.6	6	a25	do.	580	2.6	7-10-64	Jet	200	D	
302-844-1	do.	R. Coleman	1953	Drl	r60	6	48	do.	580	--	--	Jet	200	D	H_2S; water-bearing zone at 48 ft (r).
302-846-1	do.	A. Hardy	1953	Drl	46.4	6	--	do.	580	11.6	7-10-64	Jet	--	Ir	Used only to water garden; iron.
302-848-1	do.	E. Czlapinski	1951	Drl	33.5	6	--	do.	575	11.8	7-10-64	Sw	--	U	Original depth 47 ft (r); partly filled in by silt from tile drain emptying into well.
302-851-1	Niagara	Durez Div., Hooker Chemical Corp.	1938	Drl	r105	12	36	do.	575	r28.3	4-23-45	Tur	--	I	H_2S; cased to 42 ft; pumping rate 1,200 gpm (r); infrequently used because quality of water is poor.
-2	do.	do.	1947	Drl	r106	10	50	do.	575	p60.5	9-10-63	Tur	200,000	I	Anal; H_2S; pumping rate 350 gpm (r).
-3	do.	do.	1948	Drl	r107	12	--	do.	576	p,r78	5- 8-58	Tur	1,000,000	I	Anal; H_2S; pumping rate 750 gpm (r).
302-855-1	Erie	V. Konefal	--	Drl	40.4	6	--	do.	575	7.5	7- 9-64	Sw	--	Ir	Anal; H_2S; used only for watering garden.
302-858-1	do.	L. Runions	1957	Drl	44.4	6	a30	do.	575	11.7	7- 9-64	Jet	--	Ir	Iron; used only for watering garden.
303-823-1	Genesee	R. Long	--	Dug	27.5	30	--	Till	720	20.4	8-20-63	Sw	50	D	Anal.
-2	do.	H. Wallace	1961	Drl	28.4	6	a20-25	Camillus Shale	760	24.8	8-20-63	Sw	300	D	Anal; temp 49.1.
303-826-1	do.	J. Patterson	1961	Drl	26.7	6	--	do.	665	20.2	8-22-63	Sw	50	D	Anal; temp 49.5; yield 12 gpm (r).
303-828-1	Erie	J. Laughlin	1942	Drl	39.4	6	--	Sand	640	12.0	8-22-63	Jet	400	Ag	Drilled and cased to 42 ft (r); used only for watering stock during grazing season.
303-829-1	do.	Dande Farms Country Club, Inc.	1960	Drl	25.8	6	--	Camillus Shale	665	14.9	8-22-63	Sw	300	C	Anal.
303-830-1	do.	G. Cook	1941	Drl	18.2	6	--	Sand and gravel	630	p10.3	8-22-63	Sw	350	F	Do.
303-831-1	do.	F. Frey	1945	Drl	26.5	6	--	Camillus Shale	615	5.3	8-22-63	Sw	350	D	Do.
303-834-1	do.	M. Logel	1960	Drl	37.7	6	--	do.	600	13.6	8-22-63	Jet	400	D	Anal; iron; not used for drinking.
303-836-1	do.	G. Thompson	--	Drl	33.3	4	--	do.	590	Flow	--	--	5,500	D	Anal; temp 49.8, 8-23-63; flows 4 gpm 0.3 ft above LS.
303-840-1	do.	C. Scherer	1963	Drl	61.0	6	58	do.	587	6.2	8-23-63	Jet	200	D	Anal; iron; yield 10 gpm (r); water for laundering is purchased and stored in a cistern.
303-844-1	do.	W. Gallagher	--	Dug, Drl	r71	72, 6	--	do.	578	r18	--	--	--	A	
303-846-1	do.	E. Hirsch	1956	Drl	69.4	6	--	do.	579	19.7	8-28-63	Jet	--	Ir	Anal; iron; H_2S; used only for watering lawn.

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
303-850-1	Niagara	The Wurlitzer Co.	1949	Drl	69.3	8	34	Camillus Shale	577	p43.0	8-28-63	--	--	A, I	Iron; H_2S; pumping test 700 gpm, swl 30 ft, dd 10 ft after 24 hours discharge; water-bearing zone, 67-70 ft; OW.
-2	do.	do.	1951	Drl	r70	10	a42	do.	577	r,p47	6-51	Tur	500,000	I	Iron; H_2S; pumping test 660 gpm, water level at start of pumping, 47 ft (affected by pumping of well 303-850-1), dd 8 ft; water-bearing zone, 68-70 ft.
304-836-1	Erie	C. Shephard	1944	Drl	64.0	6	--	do.	590	7.5	8-23-63	Jet	200	D	Anal.
304-842-1	do.	C. Diebold	1948	Drl	r41	6	--	Sand	585	16.6	8-23-63	Jet	250	D	Do.
-2	do.	E. Stahl	1945	Drl	68.1	6	--	Camillus Shale	580	16.1	8-23-63	Sw	5	Ir	Anal; H_2S; temp 51.0; used only for watering garden; rainwater caught in a cistern is used for bathing and laundering.
304-843-1	do.	W. Lavocat	1945	Drl	69.5	6	--	do.	580	15.7	8-23-63	Sw	100	D	Anal; iron; drilled to 75 ft, bedrock at 70 ft (r); a nearby abandoned well 90 ft deep yielded so-called black water.
304-851-1	Niagara	D. Freck	1955	Drl	68.2	6	a60	Lockport Dolomite; Camillus Shale	575	18.8	10-20-60	Jet	300	D	Anal; iron; H_2S; bailed 8 gpm.
305-838-1	Erie	V. Yoder	1958	Dug	29.3	48	29	Gravel; Camillus Shale	595	15.2	8-23-63	Sw	300	D	Anal; temp 50.0.
305-845-1	Niagara	W. Wendt	--	Dug	16.5	30	--	Till	620	10.9	8-28-63	Sw	--	U	Anal; temp 49.8.
305-847-1	do.	H. Westfall	1948	Drl	73.7	6	--	Camillus Shale	625	47.7	8-28-63	Jet	400	D	Anal; iron; yield 30 gpm (r).
305-853-1	do.	F. Lemke	--	Dug, Drl	r50	36, 6	r25	Camillus Shale; Lockport Dolomite	575	11.9	10-20-60	--	--	Ag	H_2S.
306-825-1	Genesee	A. Kenward	1962	Drl	58.1	6	--	Camillus Shale	625	10.9	7- 8-64	Sw	200	D	
306-827-1	do.	R. Cheney	a1925	Dug	9.8	30	--	Sand	620	6.2	8-16-63	Sw	10	D	Anal; used only for drinking water.
-2	do.	do.	a1935	Drl	16.0	6	--	do.	620	3.3	8-16-63	--	--	A	
306-834-1	Niagara	R. Campbell	1955	Drl	37	6	--	Camillus Shale	595	p8.5	8-16-63	Sw	300	D	Anal; iron; H_2S.
-2	do.	D. Walters	--	Drl	--	6	--	do.	600	Flow	--	--	--	U	Anal; iron; H_2S; temp 49.8, 8-16-63; well is obstructed, free depth is 5.1 ft.
306-836-1	do.	S. Lackl	1960	Drl	39.8	6	--	do.	592	3.4	7- 3-64	Sw	350	D	H_2S.
306-837-1	do.	H. Sinclair	1962	Drl	38	6	--	do.	592	4.3	7- 3-64	Sw	100	D	Do.
306-840-1	do.	J. Leis	1961	Drl	67.1	6	--	Lockport Dolomite	630	26.5	8-15-63	Jet	200	D	Anal.
306-844-1	do.	L. Duszynski	--	Drl	31.8	6	--	Camillus Shale	587	6.5	7- 3-64	Sw	300	D	Iron; yield 50 gpm (r).
307-828-1	do.	G. Frainer	1963	Drl	99.5	6	85	Lockport Dolomite	645	24.2	7- 8-64	Jet	250	D	Anal; H_2S; yield 30 gpm (r) (bailed).
307-841-1	do.	Great Lakes Battery Co.	--	Drl	23.7	6	--	do.	600	.4	8-15-63	--	--	A	
307-845-1	do.	B. McMichael	1961	Drl	53.0	6	--	do.	595	23.9	8-14-63	Jet	50	D	Anal; used only for toilet and watering lawn.
307-849-1	do.	N. Bartel	1954	Drl	21.9	6	--	do.	615	12.0	8-14-63	Sw	--	U	
-2	do.	R. Gurney	1940	Drl	24.3	6	6	do.	620	9.3	8-14-63	--	--	U	Bailed 6 gpm (r).
-3	do.	G. Krantz	1957	Drl	27.0	6	--	do.	620	6.8	8-14-63	Sw	--	C	Water contains detergent; temp 54.
308-832-1	do.	H. Wagner	1958	Drl	47	6	--	Lockport Dolomite; sand	655	10.2	7- 8-64	Jet	100	D	

Table 6.--Records of selected wells in the Erie-Niagara basin (Continued)

Well number	County	Owner	Year completed	Type of well	Depth of well (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Method of lift	Estimated pumpage or flow (gallons per day)	Use	Remarks
308-833-1	Niagara	H. Keyes	1925	Drl	45	6	--	Lockport Dolomite	635	12.2	7- 8-64	Sw	250	D	
308-836-1	do.	C. Walker	--	Drl	22.2	6	--	do.	605	1.3	8-23-61	Sw	200	D	
308-838-1	do.	R. Rickard	1955	Drl	31	6	--	do.	640	23.9	8-15-63	--	--	U	Anal; yield about 10 gpm.
308-841-1	do.	J. Smith	--	Drl	48.0	6	16	do.	615	2.3	8-16-61	Sw	--	U	H_2S; water-bearing zone at 25 ft.
-2	do.	G. Gill	1954	Drl	20.9	6	--	do.	615	4.8	8-16-61	Sw	200	D	H_2S.
-4	do.	J. Molinson	1956	Drl	30	6	10	do.	610	1.8	8-16-61	Jet	--	D	Bailed >40 gpm.
308-846-1	do.	A. Stahl	a1945	Drl	43.1	6	--	do.	610	p11.3	6-13-61	Jet	100	D	
-2	do.	do.	--	Drl	36.6	6	--	do.	610	3.5	6-13-61	--	--	Ag	
308-847-1	do.	M. Drinkwalter	1961	Drl	48.4	6	3	do.	620	3.8	6-13-61	Jet	100	D	H_2S.
308-850-1	do.	U.S. Air Force	1949	Drl	r63	6	10	do.	625	p27.5	6- 8-61	--	--	PS	Anal; H_2S; pumped at 90 gpm, dd 3 ft; this well and well 308-850-2 yield a combined total of 50,000 to 70,000 gpd.
-2	do.	do.	1950	Drl	r61	6	8	do.	623	p33	6- 8-61	--	--	PS	Anal; H_2S; pumped at 82 gpm; see remarks for well 308-850-1.
309-848-1	do.	W. Comer	1960	Drl	49.6	6	9	do.	635	6.8	6-13-61	Sw	--	D	H_2S; bailed 10 gpm (r).
310-845-1	do.	B. Lovell	1940	Drl	33.8	6	--	do.	640	15.0	6- 8-61	Sw	200	D	

Table 7.--Records of selected springs in the Erie-Niagara basin

Spring number: See "Well-Numbering and Location System" in text for explanation.

Altitude above sea level: Estimated from topographic maps to the nearest 5 feet.

Yield: e - estimated
All other yields are measured.

Use: Ag - agricultural
D - domestic
F - dairy farm
In - institutional
PS - public supply
U - unused

Remarks: Anal - chemical analysis given in this report.

Spring number	County	Owner	Topographic situation	Source of spring	Altitude above sea level (feet)	Yield (gallons per minute)	Temperature (°F)	Date of yield and temperature measurement	Use	Remarks
220-850-1Sp	Cattaraugus	L. Gregory	On sloping valley floor at foot of terrace scarp	Seepage from sand and gravel	1,230	e3	46.5	5-15-63	F	Anal; water is pumped to house and barn.
227-847-1Sp	Erie	--	Terrace scarp	Seepage from sand and gravel colluvium overlying lake deposits and till	1,000	2	52.0	7- 4-63	U	Anal.
228-829-1Sp	Cattaraugus	Village of Delevan	do.	Seepage from sand and gravel	1,600	e10	49.0	7-23-63	PS	Anal; one of several springs providing water for Delevan by gravity system.
-2Sp	do.	do.	do.	do.	1,600	11	45.5	7-23-63	PS	Do.
229-842-1Sp	Erie	W. Adams	do.	Seepage from sand and gravel overlying glacial lake clay	1,320	e20	44.0	5- 7-64	Ag	Anal; water is driven by hydraulic ram to barn 1,000 feet from spring.
229-845-1Sp	do.	J. Cieszynski	Head of gulley in terrace scarp	do.	1,340	e20-30	45.8	5-29-63	F	Anal; water is pumped 500 feet to house and barn.
231-856-1Sp	do.	Erie County Highway Dept.	East side of road cut through edge of terrace	do.	780	1	56.5	9- 4-64	In	Anal; a 6-inch diameter drain tile serves as collecting basin; total seepage in immediate area of spring is 10 gpm; spring is used by highway workers and travelers; a similar spring and seeps are on west side of road cut.
232-855-1Sp	do.	Lawtons Water Co.	Hillslope	Seepage from sand and gravel overlying till	930	--	46.7	1-18-63	PS	Three openings developed with spring boxes several feet long; yield exceeds 10 gpm.
242-846-1Sp	do.	B. Fletcher	Gulley bottom	Seepage from sandy zone in lake deposits	820	<1	48.5	7-24-63	U	Anal.
251-801-1Sp	Wyoming	E. Proefrock	Hillside	Seepage from till	1,150	--	--	--	D	Anal; fails in late summer.

Table 8.--Chemical analyses of ground water from the Erie-Niagara basin

Well number: See "Well-Numbering and Location System" in text for explanation.

Depth of well: All depths below land surface.
r - reported
all others measured.

Water-bearing material:
Cam - Camillus Shale
Dol - Lockport Dolomite
Ls - Onondaga Limestone
Bertie Limestone
Akron Dolomite
Sgd - Stratified glacial deposits
Sh - Shale
T - Glacial till

Remarks: Data on wells in table 6. Location of wells in plate 1.
All analyses made by U.S. Geological Survey, Water Resources Division.

(Results in parts per million except specific conductance, pH, color, and turbidity)

Well number	Depth of well (feet)	Water-bearing material	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Alkyl benzene sulfonate (ABS)	Turbidity
a/ 219-851-1	r218	Sgd	7-10-63	--	12	0.18	0.00	39	7.6	25	0.4	168	25	14	0.1	0.0	212	129	0	354	7.5	3	0.0	0.3
226-838-4	21	Sgd	7-27-62	--	8.6	.25	.12	71	20	4.8	.8	313	23	3.0	.2	.0	296	260	3	520	7.4	3	--	.6
-5	11	T	5-15-62	--	6.1	b/ .03	b/ .01	42	7.6	2.3	.3	148	18	2.1	.1	.0	159	137	15	273	7.6	4	--	4
226-839-1	6	Sgd	5-19-62	40	3.9	.02	.0	19	3.0	2.0	.9	25	22	6.0	.0	18	103	60	40	155	6.1	2	--	--
-4	156	Sh	7-27-62	54	5.5	.53	.10	17	4.0	48	2.3	174	12	12	.3	.1	193	59	0	334	7.7	9	--	2
227-838-2	11	T	5-14-62	55	6.9	b/ .05	b/ .00	43	7.1	1.9	.5	148	17	1.5	.1	.0	154	137	15	271	7.8	2	--	--
c/ 227-856-1	r376	Sgd	7- 9-63	56	14	.79	.00	39	11	54	1.2	279	4.2	22	.2	.0	292	143	0	488	7.2	4	.0	.9
232-825-1	r53	Sgd	7-10-63	53	5.9	.01	.01	55	8.2	4.6	.5	182	21	7.6	.0	4.8	208	171	22	354	7.4	3	.0	.8
235-904-1	r55	Sh	7- 9-63	52	13	.29	.03	47	15	56	1.4	290	.2	52	.3	.1	341	179	0	590	7.3	3	.1	.6
241-855-1	r22	Sh	8-15-63	55	17	.44	.02	75	26	25	1.9	388	6.9	18	.2	.1	377	294	0	668	7.2	7	.0	2
246-836-1	r105	Sgd	6-19-51	--	13	b/ .04	b/ .45	136	12	48	20	322	133	92	.2	.3	640	389	125	1,020	7.4	15	--	--
-4	r122	Sgd	7-10-63	51	12	.94	.11	113	24	29	.8	300	104	66	.1	.1	575	381	135	832	7.2	4	.0	.6
d/ 248-850-1	r40	Sh	6-11-51	53	17	b/ .10	b/ .00	184	41	58	5.2	501	185	104	.0	.3	841	628	217	1,320	7.1	25	--	--
252-850-1	r180	Ls; Cam	6-19-51	54	15	.08	b/ .22	212	124	197	13	500	560	350	.4	.4	1,720	1,040	629	2,310	6.8	10	--	--
252-852-3	127	Ls	6-18-51	--	14	5.6	b/ .35	254	62	402	16	499	150	860	.5	.5	2,000	890	81	3,680	7.3	20	--	--
254-829-1	r36	Sgd	7-10-63	48	11	.19	.10	130	18	9.7	.2	255	179	19	.0	.0	536	399	190	772	7.3	4	.0	.9
257-824-1	r39	Sgd; Sh	7-10-63	50	16	.02	.00	59	20	6.6	.2	251	33	7.6	.1	.0	270	230	24	459	7.4	2	.0	.4
e/ 259-809-2	r69	Sgd	5- 7-63	56	8.9	.02	.00	80	22	20	2.2	315	35	30	.1	.2	360	290	32	624	7.4	2	.0	--
304-851-1	r68	Dol	10-20-60	--	11	.07	.0	520	164	437	9.8	102	1,840	658	1.2	1.7	3,990	1,970	1,890	4,740	7.7	2	--	--

a/ Partial analysis of sample collected May 15, 1963 in table 9.

b/ In solution when analysed.

c/ Partial analysis of sample collected February 20, 1963 in table 9.

d/ Partial analysis of sample collected March 20, 1963 in table 9.

e/ Partial analysis of sample collected May 6, 1963 in table 9.

Table 8.--Chemical analyses of ground water from the Erie-Niagara basin (Continued)

Well number	Depth of well (feet)	Water-bearing material	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color	Alkyl benzene sulfonate (ABS)	Turbidity
																		Calcium, magnesium	Noncarbonate					
306-834-1	37	Cam	8-16-63	53	10	0.07	0.03	300	96	17	1.9	240	914	20	1.5	0.5	1,500	1,140	948	1,820	7.1	2	--	--
308-850-1	r40	Dol	8- 7-57	50	12	1.2	.22	112	42	f/ 9.4	--	382	118	25	.3	.6	557	452	139	842	6.9	12	--	0.0
Do.	g/r63	Dol	11-18-58	45	11	.66	.16	144	50	f/ 27	--	429	196	47	.7	.6	739	566	214	1,090	6.9	8	--	.9
Do.	r63	Dol	7-21-59	52	9.9	.29	.11	316	65	f/ 30	--	356	740	40	.9	.9	1,460	1,060	765	1,740	6.6	7	--	.3
Do.	r63	Dol	10-10-60	47	9.3	.73	.1	244	52	f/ 29	--	360	516	36	.9	.9	1,200	824	529	1,490	6.9	4	--	--
Do.	r63	Dol	2- 6-62	50	8.2	.47	.2	116	40	f/ 17	--	341	156	33	.4	.9	558	454	175	843	7.0	9	--	.7
Do.	r63	Dol	10- 9-62	50	9.1	1.2	.17	127	43	f/ 21	--	363	163	50	.5	1.3	625	494	197	969	6.9	3	--	.7
Do.	r63	Dol	10- 8-63	58	9.5	1.3	.08	113	41	f/ 24	--	348	138	50	.5	4.0	565	451	166	910	8.1	6	--	2
Do.	r63	Dol	10- 1-64	56	8.4	8.4	.05	124	40	f/ 21	--	368	144	47	.7	.5	604	474	173	918	7.8	7	--	2
Do.	r63	Dol	10- 7-65	55	9.4	3.3	.22	124	46	f/ 32	--	370	151	75	.5	1.1	665	499	196	1,050	7.6	5	--	.9
308-850-2	r41	Dol	9-17-56	54	11	.35	.15	106	43	f/ 13	--	358	131	26	.7	.5	529	441	148	834	7.1	5	--	.3
Do.	r41	Dol	8- 7-57	52	12	.69	.05	107	44	f/ 9.7	--	354	133	27	.9	.1	556	448	158	836	7.3	13	--	.6
Do.	r41	Dol	7-23-58	50	9.4	.53	.04	100	43	f/ 15	--	338	137	27	.8	.3	547	427	150	815	7.2	7	--	.0
Do.	g/r61	Dol	7-21-59	52	9.4	1.2	.17	248	68	f/ 43	--	360	585	61	.9	.2	1,280	899	604	1,600	6.8	2	--	.4
Do.	r61	Dol	10-10-60	48	8.8	.14	.0	120	44	f/ 78	--	340	208	106	.6	4.0	831	481	202	1,260	7.2	2	--	.7
Do.	r61	Dol	2- 6-62	51	9.2	.74	.01	100	42	f/ 27	--	331	130	49	.9	3.2	536	422	151	901	7.2	4	--	.6
Do.	r61	Dol	10- 9-62	54	9.5	1.2	.16	118	44	f/ 14	--	342	151	46	.9	.7	592	476	195	903	7.0	3	--	.9
Do.	r61	Dol	10- 8-63	52	9.3	.89	.07	111	42	f/ 12	--	334	134	42	.9	.7	530	450	176	868	7.7	4	--	.2
Do.	r61	Dol	10- 1-64	50	8.8	3.1	.12	112	42	f/ 18	--	340	146	42	1.0	.1	564	452	174	871	7.8	7	--	.6
Do.	r61	Dol	10- 7-65	53	8.6	1.1	.07	108	42	f/ 19	--	332	143	44	.9	.1	560	444	179	883	7.5	4	--	.8

f/ Sodium and Potassium, as Sodium.

g/ Redrilled August, 1958.

Table 9.--Chemical analyses of selected chemical constituents and characteristics of ground water from the Erie-Niagara basin

Site number: Well, spring, or miscellaneous number; see "Well-Numbering and Location System" in text for explanation.
Depth of well: All depths below land surface. r-reported, all others measured.

Water-bearing material: Dol, Lockport Dolomite; Sal, Camillus Shale of Salina Group; LS, Onondaga Limestone, Bertie Formation, and Akron Dolomite; Sgd, Stratified glacial deposits; T, glacial till; Sh, Shale.

Remarks: Data on wells and springs in tables 6 and 7. Locations of wells, springs and miscellaneous sites on plate 1. All analyses made by U.S. Geological Survey, Water Resources Division.

(Results in parts per million except specific conductance and pH)

Site number	Depth of well (feet)	Water-bearing material	Date of collection	Sulfate (SO_4)	Chloride (Cl)	Calcium, magnesium-hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)	pH
218-843-1	r39.5	Sgd	5-13-63	30	4.0	122	272	7.8
219-843-1	81.5	Sgd	5-14-63	31	3.8	132	292	7.8
a/219-851-1	r218	Sgd	5-15-63	27	14	125	352	7.6
220-845-1	r90	Sgd	5-14-63	26	4.0	133	296	7.9
220-846-1	r96	Sgd	5-14-63	20	3.0	113	256	7.8
220-847-1	135	Sgd	5-14-63	15	2.1	98	244	8.1
220-850-1	67.2	Sh	5-15-63	16	16	106	251	7.2
220-850-1Sp		Sgd	5-15-63	17	3.0	172	343	7.5
b/221-840-B		Sgd	4-29-63	13	2.0	62	140	7.7
221-841-2	2.8	Sgd	5- 2-63	12	1.6	79	179	7.8
221-849-1	r135	Sh	5-14-63	22	8.4	153	322	7.6
222-848-1	r315	Sgd	5-22-63	13	.8	89	245	7.7
222-848-2	r374	Sgd	5-22-63	2.8	90	66	601	7.2
223-836-1	r230	Sh	7-22-63	4.9	6.5	52	187	7.6
223-836-2	6	Sgd	7-22-63	19	19	154	329	8.0
223-847-1	r255	Sgd	5-23-63	1.0	67	191	886	7.5
223-848-1	r438	Sgd	5-21-63	2.0	87	38	695	7.4
223-848-2	r300	Sgd	5-22-63	.2	14	68	457	7.6
224-836-1	r360		7-22-63	.0	13	77	262	7.8
225-841-1	148	Sh	9-17-64	16	242	108	1,400	8.0
226-825-1	156	Sh	6- 5-64	9.6	3.4	138	298	8.0
226-839-3	11	T	5-31-63	22	4.0	42	116	6.1
226-851-1	r137	Sh	5-24-63	3.5	2.0	80	322	8.3
c/ 226-855-E		Sgd	7- 5-63	25	5.9	397	718	7.2
227-847-1Sp		Sgd	7- 4-63	87	2.0	278	532	7.8
227-852-1	33	Sgd	5-24-63	64	3.6	173	363	7.9
227-856-1	r376	Sgd	2-20-63	4.7	26	142	510	7.3
227-856-6	r300	Sgd	2-17-64	1.8	43	160	553	7.5
228-829-1Sp		Sgd	7-23-63	17	2.0	153	289	7.7
228-829-2Sp		Sgd	7-23-63	17	3.8	156	308	8.0
228-846-1	9	Sgd	5-29-63	17	2.0	98	215	7.2
228-851-1	r110	Sh	5-24-63	22	2.0	149	341	7.7
229-819-3	39.2	Sgd	5-15-64	19	22	192	893	8.0
229-842-1Sp		Sgd	5- 7-64	18	4.0	51	131	6.7
229-845-1Sp		Sgd	5-29-63	32	5.6	160	347	7.6
229-846-1	11	Sgd	5-29-63	17	1.0	22	66	6.3
230-829-1	r244	Sgd	8- 4-64	4.4	2.5	136	292	7.6
230-833-1	56	Sgd	8- 5-64	27	8.5	144	374	7.5
230-837-1	34	Sgd	8- 5-64	16	.2	151	327	7.7
230-842-1	125	Sh	7-28-64	27	119	157	1,080	7.5
230-856-2	r36	Sgd	8-12-64	98	10	301	573	7.7
230-856-3	30	Sgd	8-12-64	56	14	328	624	7.5
231-833-2	59	Sgd	8- 5-64	23	1.5	189	399	7.6
231-835-1	100	Sgd	8- 6-64	52	7.1	206	423	7.2
231-856-1Sp		Sgd	9- 4-64	72	24	304	552	7.9
232-830-1	175	Sgd	8-11-64	.0	17	112	416	8.1
232-831-1	r87	Sgd	8-11-64	25	3.0	154	289	8.1
233-838-4	126	Sh	8-11-64	3.8	16	78	470	7.8
233-839-1	528	Sgd	8-28-63	9.5	13	87	549	7.8
234-823-1		Sh	5- 4-64	4.8	220	90	1,200	7.4

a/ Complete analysis of sample collected July 10, 1963 in table 8.
b/ Ground water flowing from a gravel bed in a sand and gravel pit, water temperature 44.5°F.
c/ Ground water flowing from a gravel deposit overlying till, 4-6 ft above the level of Cattaraugus Creek at low flow.

Table 9.--Chemical analyses of selected chemical constituents and characteristics of ground water from the Erie-Niagara basin (Continued)

Site number	Depth of well (feet)	Water-bearing material	Date of collection	Sulfate (SO_4)	Chloride (Cl)	Calcium, magnesium-hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)	pH
d/234-830-1		Dol	3- 7-64	572	149,000	37,800	186,000	7.0
234-840-1	130	Sh?	7-30-64	2.0	14	84	332	8.0
234-840-2	7	Sgd	8-27-63	81	8.0	244	468	7.3
234-846-1	55	Sgd	8-27-63	39	1.4	165	320	7.8
234-846-2	6	Sgd	8-27-63	29	12	120	264	7.4
235-830-1	25	Sgd	8-12-64	49	5.0	251	467	7.8
235-837-1	88	Sgd	8-12-64	8.4	13	78	351	7.6
235-842-1	r99	Sgd	8-28-63	9.7	4.6	134	364	7.6
235-848-1	38	Sh	8-27-63	80	19	270	585	8.0
236-830-1	r200	Sgd	11-20-64	7.2	3.6	192	355	7.9
236-839-3	115	Sgd	8-12-64	0	47	140	433	8.5
236-843-2	r113	Sgd	8-22-63	3.0	12	258	536	7.4
236-843-3	r87	Sgd	8-22-63	7.1	7.6	208	472	7.5
236-843-4	r148	Sgd	8-22-63	40	10	148	389	7.5
236-848-1	19	Sh	8-26-63	71	14	170	470	7.2
236-849-1	27	Sgd	8-26-63	42	2.2	160	312	7.7
237-850-1	r65	Sh	8-26-63	24	56	147	628	7.2
238-823-1	18	Sgd	7-17-63	39	25	232	476	7.4
238-844-1	21	Sgd	8-21-63	6.9	10	101	271	7.4
239-823-1	45	Sgd	7-17-63	37	111	412	958	7.3
239-826-1	r46	Sh	7-17-63	7.6	50	167	411	7.7
239-826-2	108	Sgd	7-24-64	14	292	280	1,540	7.6
239-833-1	r150	Sgd	11-12-64	.4	68	160	580	7.7
239-833-2	24	Sgd	11-12-64	15	37	73	269	6.9
239-833-3	r135	Sgd	11-12-64	3.0	80	200	562	7.7
239-841-1	61	Sh	8-12-64	11	66	285	764	7.5
239-845-1	r212	Sgd	8-21-63	16	62	128	618	7.6
239-854-1	60	Sh	8-15-63	29	23	99	343	7.4
239-855-1	52	Sh	8-15-63	57	12	236	462	7.6
240-819-1	r253	Sh;Sgd?	7-23-63	18	10	87	370	8.0

Site number	Depth of well (feet)	Water-bearing material	Date of collection	Sulfate (SO_4)	Chloride (Cl)	Calcium, magnesium-hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)	pH
240-819-2	4	Sgd	7-23-63	20	3.8	148	292	7.7
240-823-1	57	Sh	7-17-63	39	7.0	232	445	7.5
240-826-1	107	Sh	7-17-63	36	1,000	520	3,600	7.0
240-845-1	12	Sgd	8-22-63	44	14	88	268	6.6
240-852-1	25	T	3- 5-63	50	74	321	837	7.4
241-826-1	236	Sgd	7-17-63	3.1	12	220	523	7.5
241-841-2	r44	Sh	8-12-64	17	64	244	641	7.2
241-844-1	56	Sh	4-23-64	8.8	56	140	458	7.0
241-846-1	19	Sgd	8-21-63	9.7	21	89	294	7.3
241-847-1	16	Sgd	8-21-63	42	3.2	260	484	7.8
241-854-1	36	Sh	8-15-63	11	69	170	1,290	7.4
242-827-1	143	Sgd	7-19-63	.0	12	151	369	7.4
242-834-1	78	Sgd	8-14-63	21	123	118	1,120	7.4
242-843-1	59	Sh	7-25-63	2.0	256	92	1,570	7.6
242-846-1	r60	Sgd	7-24-63	17	52	195	508	7.5
242-846-1Sp		Sgd	7-24-63	261	28	558	1,030	7.2
242-847-1	r134	Sgd	8-29-63	1.4	6.2	220	452	7.8
242-852-1	40	Sh	7-22-63	1.6	26	237	602	7.3
242-852-2	42	Sh	7-22-63	.0	30	230	581	7.4
e/242-854-1	30	Sh	7-22-63	122	74	489	993	7.2
243-814-1	63	Sh	8-12-63	31	3.6	176	349	7.4
243-827-1	177	Sgd	7-18-63	2.2	3.0	142	298	7.9
243-828-1	r62	Sgd	7-18-63	36	6.4	283	561	7.3
243-835-1	41	Sgd	8-14-63	14	85	196	755	7.7
f/243-847-1	62	Sh	7-23-63	5.5	1.0	415	778	7.1
243-848-1	62	Sh	7-27-63	.0	3.6	288	604	7.3
g/243-853-1	52	Sh	7-22-63	5.9	120	370	1,010	7.0
243-854-1	28	Sh	7-22-63	359	78	725	1,330	7.6
243-855-1	r50	Sh	7-22-63	789	40	1,180	1,860	7.1
244-824-1	28	Sh	7-20-63	19	4.2	172	330	7.4

d/ Iron (Fe) - 5.6 ppm, in solution when analyzed, manganese (Mn) - 0.69 ppm in solution when analyzed, dissolved solids at 180°C - 257,000 ppm, density at 20°C - 1.189 grams per milliliter. In dried sediment: Iron (Fe) - 6,600 ppm and manganese (Mn) - 89 ppm.
e/ Iron (Fe) - 1.2 ppm, in solution when collected.
f/ Iron (Fe) - 2.4 ppm, in solution when collected.
g/ Iron (Fe) - 4.1 ppm, in solution when collected.

Table 9.--Chemical analyses of selected chemical constituents and characteristics of ground water from the Erie-Niagara basin (Continued)

Site number	Depth of well (feet)	Water-bearing material	Date of collection	Sulfate (SO_4)	Chloride (Cl)	Calcium, magnesium-hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)	pH
244-826-1	13	Sgd	7-20-63	71	6.8	128	297	6.3
244-829-1	r148	Sgd	7-18-63	.2	8.0	166	415	7.5
244-830-1	47	Sh	7-18-63	37	18	218	437	7.5
244-835-1	93	Sgd	8-14-63	6.3	52	142	576	7.6
244-836-1	r128	Sh	8-14-63	25	12	230	514	7.4
244-844-1	51	Sh	7-25-63	7.2	340	152	1,750	7.5
h/244-846-1	65	Sh	7-23-63	42	35	247	511	7.4
244-848-1	65	Sh	7-24-63	.8	94	317	948	7.4
245-817-1	44	Sh	8-10-63	21	2.8	182	370	7.5
245-818-1	r118	Sgd	7-26-63	4.1	2.0	192	373	7.6
245-830-1	r43	Sgd;Sh	7-18-63	74	10	258	503	7.6
245-846-1	58	Sh	7-25-63	9.2	80	352	914	7.2
246-818-1	132	Sh	8-12-63	15	12	193	420	7.5
246-824-1	24	Sh	8-10-63	53	17	300	605	7.5
246-830-1	76	Sh	8- 2-63	54	28	198	658	7.1
i/246-833-1	r140	Sh	8- 1-63	4.0	70	180	968	7.3
246-849-1	39	Sh	7-27-63	193	16	452	853	7.3
247-823-1	37	Sgd	8- 9-63	30	2.0	212	412	7.5
247-838-1	33	Sh	7-30-63	42	154	415	934	7.1
247-840-1	40	Sh	7-26-63	15	33	248	765	7.1
247-842-1	52	Sgd	7-26-63	82	9.0	276	648	7.3
248-818-1	r140	Sh	8-12-63	12	9.0	170	432	7.5
248-825-1	r112	Sh	8- 2-63	34	11	149	387	7.1
248-828-1	r112	Sh	8- 2-63	32	9.0	219	443	7.2
248-829-1	36	Sh	8- 2-63	38	48	195	476	8.0
248-833-1	36	Sgd;Sh	8- 1-63	43	13	104	230	7.0
248-838-1	59	Sh	7-30-63	16	108	212	1,510	7.0
248-839-1	86	Sh	9-23-63	164	92	621	1,170	6.9
248-839-2	25	Sh	9-23-63	160	98	518	1,040	7.1
248-841-1	44	Sh	7-26-63	130	46	440	918	7.0
248-844-1	20	Sh	7-26-63	109	57	446	1,130	7.2
j/248-850-1	r40	Sh	3-20-63	93	124	538	1,290	6.9
249-818-1	59	Sh	8-12-63	16	3.8	251	463	7.5
249-823-1	82	Sh	8- 9-63	19	2.4	242	469	7.7
249-826-1	r70	Sh	8- 2-63	61	14	223	518	7.6
249-833-1	68	Sh	8- 1-63	11	25	175	431	7.3
249-836-1	71	Sh	7-31-63	17	65	401	1,220	6.8
249-836-2	21	Sh	7-31-63	41	14	274	826	7.1
249-840-1	22	Sgd	7-26-63	35	19	145	349	7.5
250-810-1	62	Sh	6- 9-64	.4	46	200	849	7.3
250-816-1	6	Sgd	8- 5-64	39	21	356	636	7.5
250-817-1	r195	Sgd	8-12-63	15	26	199	459	7.5
k/250-821-1		Dol	8- 6-64	1,260	118,000	40,100	154,000	7.0
250-824-1	12	Sgd	8- 8-63	74	5.6	315	624	7.8
250-835-1	51	Sh	7-30-63	49	19	307	608	7.4
251-809-1Sp		T	6-10-64	60	461	510	1,970	7.0
251-809-2	65	Sh	11-20-64	7.8	22	135	569	7.5
251-815-1	130	Sgd	11-20-64	29	3.6	124	307	8.7
251-829-1	58	Sh	8- 1-63	1.0	444	500	2,050	7.1
251-832-1	57	Sh	7-31-63	24	372	499	1,700	7.2
251-834-1	84	Sh	7-31-63	21	3.0	145	299	7.7
251-837-1	74	Sh	7-30-63	9.0	120	305	1,010	7.5
251-850-2	r116	Ls	9-11-63	104	334	338	1,750	7.2
252-818-1	r24	Sh	11- 9-64	88	18	296	568	7.8
253-824-1	41	Sgd	8- 8-63	29	2.0	205	394	7.4
253-829-1	26	Sh	7-31-63	67	4.0	332	610	7.3
253-832-1	48	Sh	7-31-63	5.7	43	170	472	7.6
253-834-1	62	Sh	7-31-63	21	9.6	225	508	7.2
253-840-1	24	Sh	7-27-63	102	51	448	998	7.3
254-826-1	68	Sh	8- 9-63	9.7	144	256	1,160	7.6

h/ Iron (Fe) - 0.79 ppm, in solution when collected.
i/ Iron (Fe) - 1.0 ppm, in solution when collected.
j/ Complete analysis of sample collected 6/11/51 in table 8.
k/ Density at 20°C - 1.46 gr

Table 9.--Chemical analyses of selected chemical constituents and characteristics of ground water from the Erie-Niagara basin (Continued)

Site number	Depth of well (feet)	Water-bearing material	Date of collection	Sulfate (SO_4)	Chloride (Cl)	Calcium, magnesium-hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)	pH
255-812-1	86	Sgd	7-17-63	0.0	9.0	167	335	8.1
256-822-1	28	Sh	7-30-64	34	103	373	986	7.7
256-831-1	52	Sh	8-19-64	16	43	290	564	7.6
1/256-834-A		Sgd	8-19-64	42	3.1	137	277	7.5
256-835-2	59	Ls	8-19-64	58	23	316	571	7.7
m/257-811-A		Sgd	7- 2-63	55	10	327	647	7.4
257-812-2	71	Sgd	6-16-64	.8	7.9	267	539	7.6
258-813-2	33	Sh	6-26-63	126	15	400	874	7.1
258-815-1	31	Sh	6-26-63	48	15	272	534	7.6
258-822-1	42	Sgd	8-19-64	38	6.8	257	496	7.6
258-833-1	63	Ls	8-18-64	69	94	400	970	7.2
258-837-1	76	Ls	8-18-64	110	28	420	720	7.3
258-843-1	62	Sal	8-14-64	1,350	19	1,660	2,280	7.3
259-809-1	r60	Sgd	5- 8-63	44	33	300	635	7.3
n/ 259-809-2	r69	Sgd	5- 6-63	47	37	298	648	7.5
259-817-1	r33	Sgd	7-23-64	182	56	500	1,120	7.3
259-822-1	70	Sgd	8-19-64	35	48	290	646	7.7
259-823-1	64	Sgd	9-17-63	14	1.8	207	445	7.5
259-830-1	32	Sgd	8-18-64	40	6.0	282	534	7.6
259-835-1	77	Sal; Sgd	8-18-64	1,580	45	1,870	2,500	7.3
259-835-2	88	Sal; Sgd	8-18-64	1,640	28	1,880	2,630	8.3
300-814-1	26	Ls	6-26-63	31	3.4	200	504	7.3
300-815-1	21	Sgd	9-16-63	35	15	320	611	7.3
300-815-2	34	Ls	9-16-63	47	18	328	624	7.5
300-817-1	r85	Ls	7-23-64	44	19	274	530	7.3
300-820-1	r60	Ls	7-22-64	16	.1	219	440	7.5
300-824-2	42	Sgd	7-23-64	59	4.7	220	430	7.5
300-831-1	39	Sal	8-18-64	1,010	26	1,400	1,980	7.3
300-833-1	46	Sal	8-18-64	1,280	10	1,570	2,270	7.3
300-839-1	26	Sal	8-17-64	1,080	160	1,640	2,560	7.3
301-813-1	r70	Ls	6-27-63	104	118	246	1,050	7.3
301-822-1	r39	Ls	7-23-64	50	38	409	829	7.3
301-838-1	41	Sal	8-17-64	1,120	8.4	1,450	2,050	7.4
302-821-1	67	Ls	8-20-63	144	96	539	1,140	7.1
302-851-2 302-851-3	r106 r107	Sal	9-10-63	1,680	2,340	2,780	9,010	7.5
302-855-1	40	Sal	7- 9-64	1,640	4.5	1,800	2,700	7.0
303-823-1	28	T	8-20-63	644	84	1,310	2,130	7.8
303-823-2	28	Sal	8-20-63	416	196	495	1,240	7.6
303-826-1	27	Sal	8-22-63	565	232	460	1,300	7.1
303-829-1	26	Sal	8-22-63	820	6.8	851	1,410	8.0
303-830-1	18	Sgd	8-22-63	428	9.6	1,100	1,710	7.4
303-831-1	27	Sal	8-22-63	1,080	34	1,380	2,090	7.5
303-834-1	38	Sal	8-22-63	1,250	650	1,690	4,270	7.4
303-836-1	33	Sal	8-23-63	1,300	22	1,640	2,390	7.3
303-840-1	61	Sal	8-23-63	1,950	300	2,000	3,660	7.5
303-846-1	69	Sal	8-28-63	1,200	136	1,440	2,650	7.5
304-836-1	64	Sal	8-23-63	1,800	605	1,960	4,510	7.1
304-842-1	r41	Sgd	8-23-63	623	230	485	1,520	8.2
304-842-2	68	Sal	8-23-63	1,120	2,520	1,920	8,420	7.2
304-843-1	70	Sal	8-23-63	1,740	580	1,850	4,190	7.6
305-838-1	29	Sgd; Sal	8-23-63	400	140	760	1,650	7.5
305-845-1	17	T	8-28-63	244	30	413	960	8.5
305-847-1	74	Sal	8-28-63	134	7.0	319	597	7.7
306-827-1	10	Sgd	8-16-63	63	7.2	216	467	7.6
306-834-2		Sal	8-16-63	232	29	477	912	7.4
306-840-1	67	Dol	8-15-63	103	2.2	304	566	7.8
307-828-1	100	Dol	7- 8-64	260	5.7	482	876	7.2
307-845-1	53	Dol	8-14-63	469	40	838	1,530	7.3
308-838-1	31	Dol	8-15-63	150	9.0	434	822	7.6

1/ Ground water flowing from a gravel bed in a sand and gravel pit.
m/ Ground water flowing from bank of Little Tonawanda Creek.
n/ Complete analyses of sample collected 5/7/63 in table 8 .